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CYTOECOLOGICAL STUDIES OF *SILENE ROTUNDIFOLIA* NUTT., *S. VIRGINICA* L., AND HYBRID¹

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This paper is the result of certain cytoecological studies of *Silene rotundifolia* Nutt., the Round-leaved catchfly, and *S. virginica* L., the Fire pink (CARYOPHYLLACEAE). *S. rotundifolia* was described by Nuttall (6) in 1807. Its habitat was described as "moist ledges of rock cliffs" in Ohio and Tennessee. Since then its distribution has been more accurately mapped from herbarium records and it is known to occur on rock ledges or in cliff crevices of limestone or sandstone throughout its range in Ohio, Tennessee, Kentucky, Virginia, West Virginia, and northern Alabama and Georgia. These habitats which are exposed to high light intensities often appear dry, but these plants are neither "xerophytes," nor is water usually a limiting factor, as the tap root of *S. rotundifolia* extends into a water source in the joint and bedding planes. Wolfe, Wareham, and Scofield (7) in their work on microclimates in southern Ohio show that the environmental conditions in rock crevices are considerably different from those in the surrounding forest and open areas.

S. virginica, which was studied in conjunction with *S. rotundifolia*, has a much wider distribution. It grows in open woodlands and forest borders in southern New Jersey, western New York and southwestern Ontario to Minnesota, and south to Missouri and Georgia (1, 4, 5). Although these two species often grow in the same region, one has never been known to invade the habitat of the other, nor has hybridization of the two been known to occur in the field.

In order to further analyze the ecological requisites of this species, hybrid material for study was obtained by crossing *S. rotundifolia* with *S. virginica*, one of the two other red flowered species of *Silene* growing in Ohio. Crosses with *S. rotundifolia* as the ovule parent and reciprocal crosses were made and repeated successfully. These species are cross fertile and approximately 100 seeds externally resembling those of the ovule parent develop in each ovulary after cross fertilization.

The F₁ hybrid, like both parents, is perennial, slender, ascending or reclining, viscid-pubescent, branched; the blades of the lower leaves taper into winged petioles, the upper leaves are sessile; the calyx is tubular-campanulate, somewhat enlarged by the ripening pod. The lower and basal leaves of the hybrid are intermediate between the obovate or broadly spatulate leaf blades of *S. rotundifolia* and the oblanceolate leaf blades of *S. virginica*. The upper leaves are intermediate between the broadly oblong or orbicular-ovate leaves of *S. rotundifolia* and oblong-lanceolate leaves of *S. virginica*. The petals of the hybrid flowers are intermediate between those of the parent species in size, color and shape. The petals are two-cleft or two-lobed as are those of both parents, but the degree of laciniation varies between the deeply incised two-cleft petals of *S. rotundifolia* and the less incised two-cleft petals of *S. virginica*.

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The number of flowers per plant and the length of the flowering period is greater in the hybrid than in either parent. The vegetative growth of the hybrid is luxuriant and many perfect flowers develop on each plant. The amount of pollen in each anther of the hybrid is much less than that of either parent, and the filaments are often weak and short. In both parent species, the petals open, five stamens elongate, the anthers begin to dehisce, and then the other five stamens and the styles elongate or the filaments elongate. This is followed by elongation of the styles and expansion of the three stigmas. Pollination usually takes place as the pistils grow to their ultimate height. However, the stamens of the hybrid sometimes never elongate, or they do not dehisce until after the pistils have grown above them, or the filaments collapse before the anthers dehisce. Thus self-pollination often fails to occur in the hybrid, but this failure was eliminated in experimentation by hand pollinating. After pollination occurs in the hybrid, the ovary begins to swell, finally dehiscing when mature; but only shrunken, shriveled ovules occur within the small capsule.

From the following breeding results it appears that the hybrid is both self and cross sterile:

<i>S. hybrid</i> ♀	×	<i>S. hybrid</i> ♂
	(repeated 1500 times)	
	no seeds	
<i>S. hybrid</i> ♀	×	<i>S. rotundifolia</i> ♂
	(repeated 131 times)	
	no seeds	
<i>S. hybrid</i> ♀	×	<i>S. virginica</i> ♂
	(repeated 103 times)	
	no seeds	

There are usually more than 100 ovules in each ovary and 1,734 hybrid flowers were either self or cross pollinated. None of the 170,000 ovules observed developed into seeds.

This failure of viable seed to develop does not appear to be the result of adverse environmental conditions as *S. rotundifolia* and *S. virginica* plants growing at the same time in conditions similar to those of the hybrid were "setting" seed in the ovaries of both cross and self-pollinated flowers. Cytological studies were then undertaken in an attempt to explain the failure of seeds to develop.

Observations of microsporogenesis were made in *S. rotundifolia*, *S. virginica*, and the hybrid.

Slides were prepared for studying microsporogenesis by smearing the anthers of one bud in acetocarmine. The anthers in the buds collected in early morning contained more pollen mother cells in desirable stages than those collected later in the day. Immediately after collection, the buds were put in a 3:1 absolute alcohol-acetic acid fixing solution. Twenty-four hours later they were transferred to a 70% alcohol solution.

S. rotundifolia pollen mother cells observed had regular meiotic divisions with the formation of four microspores. Cells observed in late diakinesis and early metaphase I contained 24 bivalents (Fig. 1 A), and those in anaphase I had 24 univalents moving toward each pole (Fig. 1 B), illustrating regular pairing and disjunction. The diploid chromosome number of *S. rotundifolia* is 48.

Microsporogenesis is also regular in *S. virginica*. Although no counts were made from cells in metaphase I, pairing was regular and all bivalents lined up on the metaphase plate as in Fig. 1 C. All cells observed in metaphase II had 24 univalents in each nucleus, (Fig. 1 D). Pairing and disjunction appear to be regular. The diploid chromosome number of *S. virginica* is 48.

Blackburn (3) reported the diploid chromosome number of 44 species of *Silene* in various sections of Europe as 24. In 1928 she reported *S. schafta* to have a diploid chromosome number of 24, 48, or 192. Love (3) in 1942 found *S. pontica* (Rumania) and *S. vallesia* (Alps) to have diploid chromosome numbers of 48.

No records of chromosome counts on American species of *Silene* were found reported in the literature. Relative to the European species, these American species appear to be basically tetraploid.

Many meiotic irregularities occur during microsporogenesis in the hybrid. Chromosome studies revealed that this hybrid has a diploid number of 48, as do both *S. rotundifolia* and *S. virginica*, and that gross morphology of all its 48 chromosomes is so much alike that it is not possible to identify those of maternal or paternal origin (Figs. 2 A-B). Pairing was highly irregular; univalents, bivalents, and

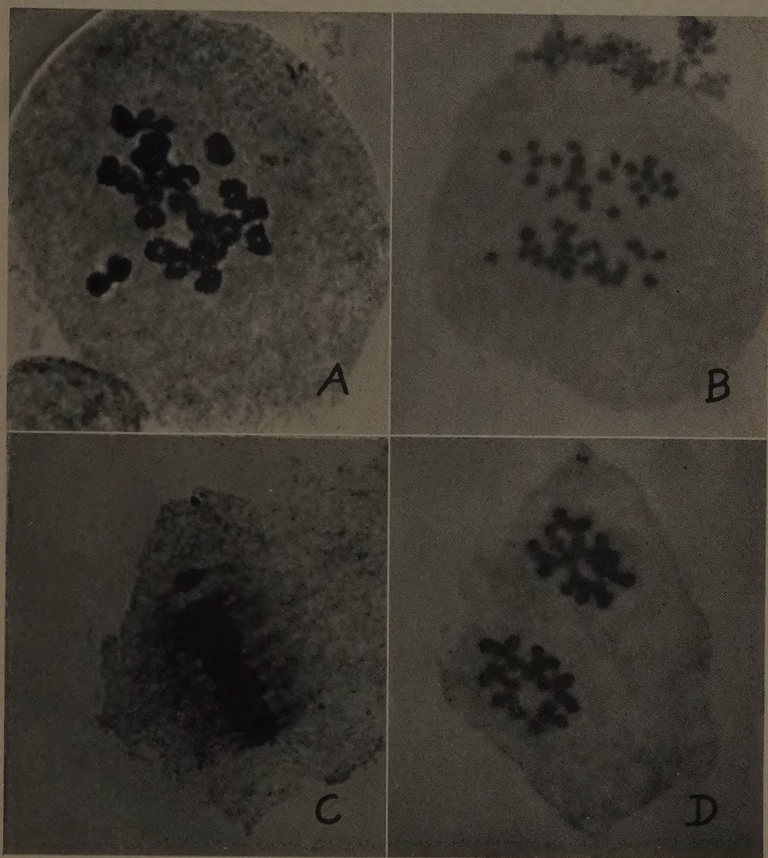


FIG. 1. (A) *Silene rotundifolia*: late diakinesis, 24 bivalents. (B) *S. rotundifolia*: anaphase I, 24 univalents moving toward each pole. Note the similar morphology of all chromosomes. (C) *S. virginica*: metaphase I. (D) *S. virginica*: metaphase II, 24 univalents in each nucleus. 1000X. Photomicrographs by Tillman J. Johnson.

multiple associations being formed in varying numbers from one cell to another (Fig. 2 B). Lagging was often observed in both the first and second meiotic divisions (Fig. 2 C). The lagging chromosomes moved at random to one pole or the other or they were sometimes incorporated in micronuclei. Although four microspores were usually formed from each microspore mother cell, the number varied from one to six (Fig. 2 D). Each of these irregularities, failure of synapsis, formation of multiple associations, lagging of chromosomes, unequal

numbers of chromosomes moving to each pole, and the formation of micronuclei, would contribute toward disturbance of the genetic balance of gametes and therefore to the sterility of the hybrid.

Although *S. rotundifolia* grows on cliff faces and rock ledges and *S. virginica* grows in open woodlands and woodland borders, they are often geographically

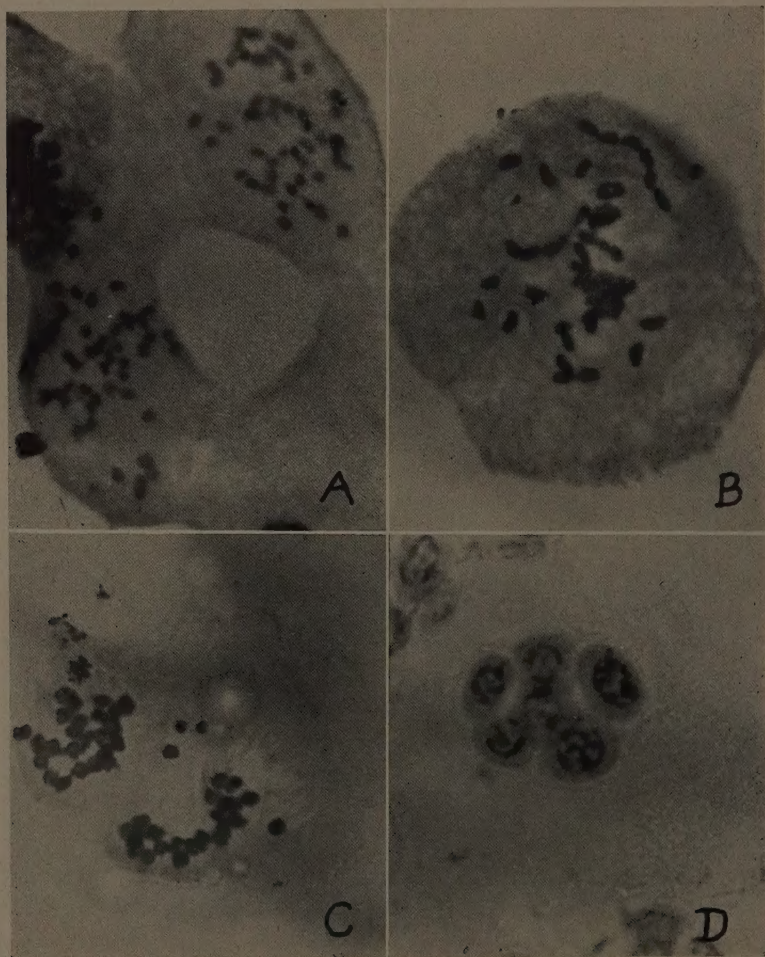


FIG. 2. (A) Hybrid: metaphase I, pairing irregular, chromosomes of each genome morphologically similar. (B) Hybrid: metaphase I, univalents, bivalents, and multiple associations present. (C) Hybrid: anaphase I, three chromosomes lagging. (D) Hybrid: polyspory (more than four spores) resulting from meiotic irregularities. 1000X. Photomicrographs by Tillman J. Johnson.

close enough for cross pollination to take place, but this does not usually occur because self-pollination takes place in both species before there would be much probability of cross-pollination.

From the experimental evidence, it is obvious that *S. rotundifolia* and *S.*

virginica are genetically similar enough to hybridize, and a vigorous vegetative hybrid develops; but the genetic dissimilarities between the two parents are great enough to result in a high degree of sterility in the hybrid. While the chromosomes of each of the above species appear to be so much alike in both number and gross morphology, the irregularities in synapsis between the two groups of chromosomes is evidence of qualitative and structural differences between the chromosome groups. Some of the chromosomes of one species have evolved so differently from those of the other species that synapsis no longer occurs between the two or if it does, no chiasmata are formed and the chromosomes separate before first metaphase, becoming univalents. Structural changes must have occurred in some chromosomes because various multiple associations greater than four are present at first metaphase of meiosis in the hybrid (Fig. 2 B). Usually only homologous portions of chromosomes synapse and thus it may be inferred that some chromosomes in the hybrid contain portions which are homologous with portions of two other chromosomes. It may then be further inferred that at some time in the evolutionary history of the parent species segmental translocations between non-homologous chromosomes may have taken place separately within one or both of the species.

An amphiploid is most likely to be fertile and vegetatively vigorous in the first and following generations if its parent species are closely enough related that a vigorous F_1 hybrid results from crosses, yet remotely enough related that the balance between their combined genomes in the F_1 hybrid can not be perpetuated (2). The present hybrid fulfilled both requirements. Therefore attempts were made to create a fertile and vegetatively vigorous amphiploid from the hybrid. Colchicine in water and in a lanolin paste at concentration of .05%, .1%, .2%, .5%, or 1.0% was applied to the growing stem tips of hybrid seedlings. However, all attempts were unsuccessful, as the colchicine only caused a temporary stunting of vegetative growth.

From cytological studies of the hybrid, it appears that if an amphiploid were to be obtained, it might not be entirely fertile during either the first or succeeding generations. Some of the chromosomes of one parent were found to be homologous with those of the other parent, a relation close enough to allow interspecific segregation in their amphiploid. This interspecific segregation might disturb the parental gamete balance and thereby produce sterility or partial sterility in the amphiploid. Furthermore, such an amphiploid would be basically octaploid.

SUMMARY

The diploid chromosome number of *Silene rotundifolia* and *Silene virginica* is reported as 48. They are therefore basically tetraploid. Microsporogenesis is regular in each of these species. Both species also are self- and cross-fertile. F_1 hybrids resulting from crossing them are vegetatively vigorous but highly self and cross sterile. It is suggested that this sterility might be attributed in part or wholly to the observed disturbance of the genetic balance of gametes by meiotic irregularities such as failure of synapsis, formation of multiple associations, chromosome lagging, and the formation of micronuclei.

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BRACHINUS ATBARAE N. SP. (COLEOPTERA, CARABIDAE)¹

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This species is very similar to *B. fumans* (Fab.) in many respects and would key to that species in the papers of Leconte, '62, Chaudoir, '68, and Blatchley, '10. The elytra are deep violet blue and the rest of the body is reddish brown with the exception of the metepimera, metepisterna and outer sixth of the abdominal segments which are blackish. The clypeus is much more convex than in *B. fumans* and the frontal striae of the head are less deeply impressed and although somewhat rugose have only a few obsolete punctures in them. These punctures are more numerous and much more distinct in *B. fumans*. The head is very smooth discally and the punctures of the area posterior to the eyes are much weaker and less numerous than in *B. fumans*. The prothorax is slightly wider in proportion to the length (6 : 5) than in *B. fumans* (5.5 : 5), the sinuation before the hind angles is greater and the hind angles are more prominent. The punctures of the prothorax are much less distinct than in *B. fumans*, but the rugosity, median line, and transverse impressions are very similar. The scutellum is finely rugose and is medially sulcate on its posterior half, whereas in *B. fumans* this sclerite is finely rugose but is not sulcate. The costae of the elytra are less developed than in *B. fumans*, and the punctuation is similar, but the hairs are shorter and less conspicuous. The next to the last dorsal abdominal segment of the male of *B. atbarae* has a very short rather blunt carina which ends in a blunt denticle on the middle of the posterior margin. There is no trace of this structure in the female and it is not present in either sex of *B. fumans*. Length: 11 to 12 mm.

Holotype male: Atbara, B. C., Canada, 24-IV-'45, G. Stace Smith, Coll.

Allotype female: Atbara, B. C., Canada, 7-V-'46, G. Stace Smith, Coll.

Paratypes: Atbara, B. C., Canada: 1 female, 26-IX-'44; 1 male, 27-IX-'44; 1 male 20-VI-'46; 1 female, 24-VI-'46; 2 males, 1 female, 5-VII-'46; 2 males, 3 females, 21-VII-'46; 1 male, 20-IX-'46. All collected by G. Stace Smith.

The Holotype, Allotype, and 5 paratypes are in possession of the author and 8 paratypes are in the collection of Mr. G. Stace Smith.

The author is indebted to Mr. G. Stace Smith, of Creston, B. C., for the opportunity to study this species. Mr. H. B. Leech had previously recognized the species as near *B. fumans* (Fab.).

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¹Paper No. 43, Department of Zoology, Ohio University, Athens, Ohio.

NEW MEMBERS

More than 150 Obioans joined the Obio Academy of Science in the month of April. Of these, more than 50 were physicians.

Is your physician a member?

BODY WEIGHT, SURVIVAL TIME, COLORATION, AND WATER CONTENT OF SKELETAL MUSCLES OF ADRENALECTOMIZED FROGS¹

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From studies of slightly more than 1300 operated frogs, of which between 65% and 70% were adrenalectomized and the remainder were renal damaged ("sham"-operated controls), various observations relative to changes in body weight, survival time, integumental coloration, and water content of skeletal muscles are available to extend, as well as to correlate, the prevailing literature relative to the effect of adrenalectomy in frogs.

Male *Rana pipiens* weighing between 30 and 35 g. may be arbitrarily divided into four groups: adrenalectomized frogs whose postoperative body weights were either (a) *controlled* to be within ± 1.5 g. of their respective mean preoperative values, or (b) *uncontrolled*; and the control frogs—(c) *renal damaged*, and (d) *unoperated*. During an interval from 10 days prior to adrenalectomy until the time of death, individual daily records were kept with regard to various pertinent data. Because of the subjective nature of interpreting integumental color changes, the same two persons² always made the observations.

All frogs were unfed. The appearance of ample testicular fat at autopsy was considered as evidence of at least a "basal" state of nutrition; otherwise the frogs were excluded from the results.

Data derived from the four groups of frogs are summarized in Fig. 1. The various mean values for the respective data for each group (25 frogs/group) have been statistically compared. Significance is considered to exist when $P < 0.05$.

Body weights. The percentage differences between the postoperative values of the body weights for each group of frogs designated in the legend under Fig. 1 and their respective preoperative values are plotted as functions of the postoperative time in days. The uncontrolled adrenalectomized frogs, unlike the three remaining groups, show a progressive increase in mean body weight so that by the seventh and twelfth days following adrenalectomy there is a significant increase of 28 and 33% respectively. Given sufficient time in an aqueous environment, the adrenalectomized frog undergoes a pronounced swelling [cf. Maes (1), p. 145]. This swelling is not only reflected in "un oedeme généralisé" but also in a cellular imbibition of fluid as shown macroscopically by the swollen, milky-white appearance of the myofibers of skeletal muscles. The progressive gain in body (water) weight becomes significant on the second day following adrenalectomy. This is interesting in light of the increased rate at which certain vital dyes and tagged ions penetrate adrenalectomized frog skin (2). That this increase is due to lack of the adrenocortical hormone and not to the localized kidney damage which tends to accompany cauterization is supported by studies on injury to this organ. Ordinarily the adrenal tissue can be "wiped" from the kidney by the convex side of a curved cautery needle. When "sham" operated frogs are damaged by longitudinally cauterizing both kidneys to a depth and width greater than necessary for removal of the adrenal, one finds no difference between the two groups of controls as regards

¹This investigation was partially supported by a grant-in-aid from the National Chapter, The Society of the Sigma Xi, and the Comly-Coleman Research Fund, The Ohio State University.

²I wish to thank Helena Angerer for her logging and valuable assistance.

the variables under discussion. Indeed, this was true even when both kidneys were deliberately split except for a segment a few mm. long at both poles, which served to bind the lateral portion of the kidney to its medial mass. That this drastic procedure is apparently not deleterious to the frog is inferred from studies in which the ureters were bilaterally ligated (3).

Survival time. Sixty-seven per cent of the uncontrolled adrenalectomized frogs of the fall and winter stock, when kept at room temperature (17° – 22° C.), died between the seventh and twelfth days postoperatively. Studies on summer and early fall frogs support Maes' (1) findings that survival is reciprocally related to environmental temperature. Spring frogs do not survive adrenalectomy as well as frogs in other seasons; possibly due to a form of stress arising during the breeding season. Indeed, "the adrenalectomized animal is abnormally sensitive to every type of stress" (4).

To test whether the abnormal increase in water load of uncontrolled adrenalectomized frogs served to alter the death point, adrenalectomized frogs were kept over sphagnum moss wetted to a degree determined from the daily observation of individual body weights. In this way, body weights were fairly well controlled (Fig. 1; cf. Adolph (5), p. 119). Cognizant of the susceptibility of adrenalectomized animals to many forms of stress, especially an increase (6, 7) or a decrease (8, 9) in water-load, it was surprising that both groups of frogs showed essentially the same duration of survival following adrenalectomy. As a result of the latter studies (9), the conclusion is reached that the rate of water shift, or of change in osmotic pressure, is the more effective factor in this type of stress.

Coloration. The horizontal bar above the curves (Fig. 1) shows the mean postoperative time in days when an apparent darkening of the dorsal integument was observed in uncontrolled adrenalectomized frogs. The mean time for the appearance of integumental darkening is the end of the second day. Thereupon a succession of characteristic integumental color changes occurred in the following sequence: green, gray-green, gray-brown, gray, and black. Evidently, Maes' (1) statement, "ce changement de pigmentation n' a pas été constant," needs revision, for adrenalectomized frogs given free access to water, and sufficient time to accrue a water load, showed the characteristic sequence of color change. Controlled adrenalectomized frogs darken, though not beyond the gray-brown (usually a gray-green) stage for comparable illumination and background. Darkening of the ventral integument occurs simultaneously, but, of course, to a lesser degree than found on the dorsum. The cause of the color change is unknown, though it is related to water load, since controlled adrenalectomized frogs do not show blackening. Hence it is suggested that this characteristic color change is related to excessive water load, which, in some as yet unknown way, affects the production of melanophore-dispersing hormone (intermedin) by the pituitary.

Skeletal muscle. Since it has been shown that there is a progressive increase in body weight of adrenalectomized frogs given free access to an aqueous environment, and that part of this water is extracellular, it is of interest to compare the water content of skeletal muscles obtained from the four groups of frogs. Pairs of sartorius muscles were rapidly excised, blotted to remove excess water, and weighed with a torsion balance by the same person. The muscles were dried for 18–22 hours at 105° C., and dry weights were determined. The mean percentage of water content for sartorii of each group follows: uncontrolled (84.6 ± 0.4) and controlled (82.8 ± 0.4) adrenalectomized frogs, and their controls . . . renal damaged (82.8 ± 0.4) and unoperated (82.0 ± 0.8) frogs. A statistical comparison of the mean values of the first group of frogs with each of the remaining groups gives a decided significance ($P < 0.01$).

Although sartorii from the uncontrolled adrenalectomized frogs have gained 1.8% in water content ($P < 0.01$), the intact frog from which these muscles were excised showed a net gain of 23.1% in water content ($P < 0.01$). Thus, while the skeletal muscles, intra- and extra-cellularly, tend to absorb water after adrenal-

ectomy, the muscles are not the sole reservoir. This is amply confirmed by the following observations. When a water-loaded, uncontrolled adrenalectomized frog is pithed, upon withdrawal of the needle, there issues from the site of puncture, undoubtedly because of the pressure exerted manually in holding the frog, a stream of fluid for a distance of *ca.* 3-5 mm.

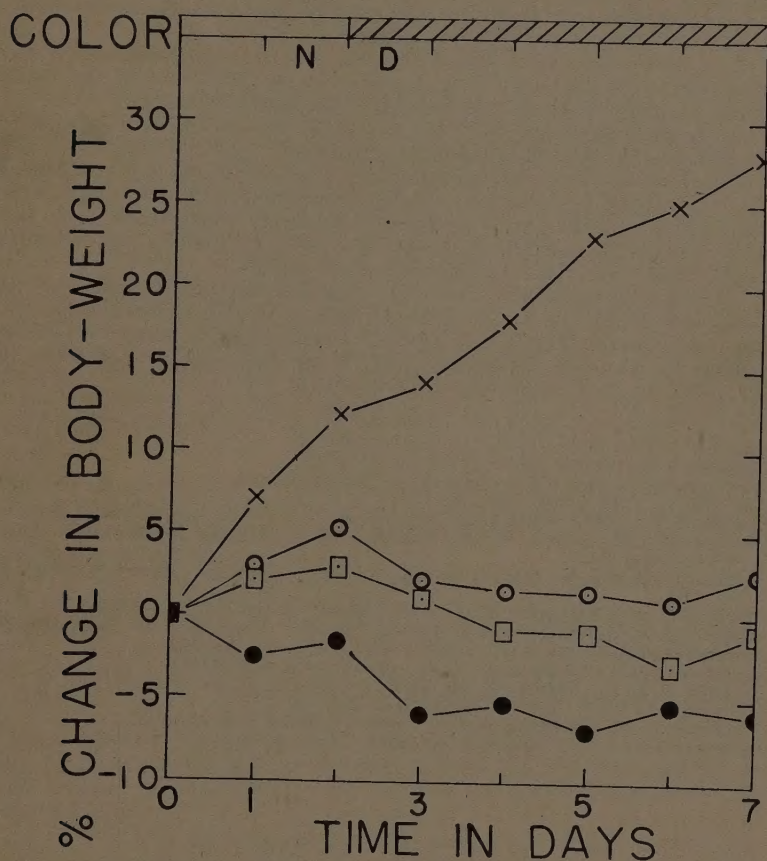


FIG. 1. Percentage changes in body weight of 4 groups of frogs plotted as functions of time. The groups are designated as follows: the adrenalectomized frogs—controlled (●) and uncontrolled (X); the control frogs—renal damaged ("sham" operated) (O) and unoperated (□). The terminations of the curves denote the mean death point for the respective groups; the shaded area of the horizontal bar over the curves signifies the mean time (days) for the initial appearance and duration of integumental darkening (D) in uncontrolled adrenalectomized frogs as compared to "normal" (N) coloration.

These results on frogs are in line with those on mammals (6), and show that the lack of adrenocortical hormone results in an imbalance in the distribution of body fluids, with an accompanying increase in the water content of the liver and the eviscerated carcass of rats (9), of skeletal muscles of rats (11) and frogs (12), and of enucleated red cells of dogs (13), cats (14), and rats (15).

SUMMARY

From a study of slightly more than 1300 operated male grass frogs, of which between 65% and 70% were adrenalectomized and the remainder were renal damaged ("sham" operated) the following conclusions may be drawn.

1. Adrenalectomized frogs whose body weights are permitted to change *ad libitum* show a progressive increase in body weights when placed in a copious aqueous environment, so that on the 7th and 12th days postoperatively there is a mean increase of 28% and 33%, respectively.

2. The mean rate of increase in water load and the total water load absorbed following adrenalectomy in the frog is a function, within limits, of the available water free to enter the integument from the external environment.

3. At room temperature (17°-22° C.), 67% of the adrenalectomized frogs die between the 7th and 12th days postoperatively.

4. The duration of survival following adrenalectomy in the frog is independent of the total increase in water load. Adrenalectomized frogs whose body weights were controlled to within ± 1.5 g. of their respective, preoperative, mean values for body weights showed the same survival time, statistically, as did adrenalectomized frogs whose body weights were uncontrolled.

5. As originally observed by Maes (1) these frogs showed integumental blackening after adrenalectomy but contrary to Maes' observation, blackening is not a sporadic occurrence. It is a function of the total increase in water load following adrenalectomy, for adrenalectomized frogs whose body water loads were "controlled" failed to show integumental blackening.

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OHIO'S STATUS AS A GAME AND FUR PRODUCING
STATE—CORRECTION

In the March, 1950, issue of the OHIO JOURNAL OF SCIENCE, I discovered the following errata in my article entitled "Ohio as a Game and Fur Producing State." On page 91, the last sentence under the heading of *Mourning dove* should appear as the second sentence under the heading *Bob-white quail*. Also, under *Mourning dove*, the third sentence should read, "Like the bobwhite, however, the dove, as a game bird in Ohio, was given protection from hunting 1913 to 1917 (rather than 1913 to 1947) and, in the latter year, was designated a song bird (Dambach, 1948)."

My name, although spelled correctly under the title of the article, page 88, had the middle initial J. in it rather than the correct initial L. at the top of pages 90, 92 and 94.—Daniel L. Leedy.

NOTES ON THE CHEMICAL COMPOSITION OF PARTHIAN COINS WITH SPECIAL REFERENCE TO THE DRACHMS OF ORODES I¹

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Over a thousand ancient coins of Greek and Roman origin have been assayed or analyzed, but only a few Parthian coins have been so investigated. It might reasonably be expected, however, that the chemical investigation of the coins of the Parthian Empire would lead to results just as interesting as those that have been obtained from the chemical investigation of the coins of other ancient states. Indeed, in view of our total lack of ancient literary information concerning the coins of this great eastern empire, it might be expected that the results of the chemical investigation of such coins would lead to results of relatively greater interest. Furthermore, since the coins constitute the chief, and almost the only certain, archaeological remains of the Parthian Empire, any information that can be obtained from a chemical study of these coins will not only be a contribution to the obscure numismatic history of this empire but may be a contribution to its still more obscure economic history. This paper contains a summary of what little has been done in the past on this subject, the results of chemical analyses of some Parthian silver and bronze coins, and interpretations of some of these results.

PREVIOUS WORK

Prior to the present investigation only 16 Parthian coins appear to have been investigated chemically in any way, and these were all silver coins that were analyzed by fire assay for their silver and gold content only. The results of these assays are shown in Table I.

From these results it would seem evident that the earliest coins contain the highest proportions of silver, and that later coins, leaving out of consideration the one late tetradrachm, contain moderately high amounts. There is no indication of any serious or progressive debasement in this series of Parthian drachms such as occurs in the series of denarii of the Roman Empire. These results also indicate that individual coins of some rulers differ considerably from each other in silver content. The proportions of gold in these coins, though high from the standpoint of modern silver coinage practice, are similar to those in the silver coins of many other ancient states. In light of the results of the present investigation, certain of these conclusions, which seem so obvious from the results of previous work, are actually not valid.

SOURCES AND IDENTIFICATION OF THE COINS

With the exception of six drachms of Orodes I, the coins analyzed in this investigation were purchased by the author from dealers here and abroad at various times. The coins of Orodes I were presented to him for purposes of chemical study by Professor S. H. Weber, formerly Curator of Special Collections, Princeton University. According to information supplied by Dr. L. C. West, Curator of Coins and Medals, Princeton University Library, they came originally from a hoard of some 600 Parthian drachms accidentally dug up by a native worker in 1923 in a small village near Ahar, 75 miles northeast of Tabriz, Persia.

The British Museum Catalogue of the Coins of Parthia, London, 1903, and

¹Presented in part at the meeting of the Ohio Academy of Science, Granville, Ohio, April, 1949.

Head's *Historia Numorum*, Oxford, 1911, were used as the principal authorities for the identification of the coins that were analyzed, due consideration being given to the uncertainties that still exist as to the proper attribution and dating of certain of the coins.

TABLE I
ASSAYS OF PARTHIAN SILVER COINS

No.	RULER	DATE	FINENESS IN PARTS PER THOUSAND	
			Ag	Au
1	Tiridates I, or Arsaces, son of Tiridates I.....	248/247-211/210 B. C.....	946	...
2	Mithradates I.....	210-191 B. C.....	...	...
3	Mithradates I.....	171-138 (?) B. C.....	923	2
4	Mithradates I.....	171-138 (?) B. C.....	899	5
5	Phraates II.....	171-138 (?) B. C.....	892	2
6	Artabanos II.....	138-128/127 B. C.....	709	3
7	Artabanos II.....	88-77 B. C.....	854	1
8	Tiridates II (?).....	88-77 B. C.....	728	2
9	Orodes II.....	26 B. C.....	611	2
10	Orodes II.....	4-6 A. D.....	798	2
11	Gotarzes.....	4-6 A. D.....	622	3
12	Gotarzes.....	40/41-51 A. D.....	805	3
13	Mithradates IV.....	40/41-51 A. D.....	755	2
14	Volagases III.....	130-147 (?) A. D.....	749	4
15	Volagases IV.....	185 A. D.....	334	1
16	Artabanos V.....	191-207/208 A. D.....	779	3
		213-227 (?) A. D.....	746	4

NOTES TO TABLE I

- a. No. 1 was assayed at the Prussian mint and the result was first published by A. von Rauch in *Zeitschrift für Numismatik* 1, 37 (1874). This coin was attributed by von Rauch to Arsaces I, probably on the basis of the inscription on it, but it is now believed that this ruler issued no coins. On the assumption that the inscription was simply $\Lambda \text{P} \Sigma \text{AKOY}$ it is here attributed to one of the two rulers listed. In spite of this uncertainty as to its exact attribution, it is reasonably certain, at least, that this coin is the earliest in the series here listed.
- b. The other coins were assayed at the Austrian mint and the results were first published by F. Imhoff-Blumer in his "Monnaies Grecques," Amsterdam, 1883, p. 474. The attributions and dates are those given by B. V. Head in "Historia Numorum," Oxford, 1911, pp. 818-822. A question mark indicates some uncertainty in attribution or date.
- c. All these coins were drachms except No. 14 which was a tetradrachm. This coin was attributed by Imhoff-Blumer to Volagases IV, but since it bore the date 497 in the Seleucid Era, this places it in the reign of Volagases III according to the system of attribution at present generally accepted.

ANALYSTS AND METHODS OF ANALYSIS

The six drachms of Orodes I were cleaned electrolytically before analysis and were analyzed by the author. The other silver coins and the bronze coins were not so treated and were analyzed by Mr. C. D. Oviatt under the direction of the author. The author hereby thanks Mr. Oviatt for his careful analytical work and the authorities of the Graduate School of the Ohio State University for a grant that enabled Mr. Oviatt to do this work.

Before being analyzed, the specific gravity of each of the silver coins was measured at 25° C/25° C by the method of Archimedes. The coins were next filed smooth and the specific gravities of the blanks were also measured by the same

method. These blanks were then divided into samples of suitable size for analysis. The specific gravities of the bronze coins were not measured, though samples were prepared for analysis in the same way.

For the analysis of the silver coins, accurately weighed samples of about a gram were treated with nitric acid for the separation of gold and tin. The ignited and weighed residue from the nitric acid treatment was extracted with cold, dilute aqua regia to dissolve the gold, and the resultant solution was diluted and treated with either ferrous sulfate or oxalic acid to precipitate the gold. This gold was then collected on paper, ignited, and weighed. By subtracting the weight of the gold from the weight of the residue, the weight of stannic oxide was obtained from which the weight of the tin was calculated. In some experiments, as a check, the weight of the stannic oxide was also measured directly. The filtrate from the separation of the gold and tin was treated with hydrochloric acid to precipitate the silver as chloride, this precipitate being collected in a filter crucible, dried, and weighed in the usual way. The filtrate from the separation of the silver was treated with sulfuric acid, and the solution was evaporated until fumes of sulfur trioxide appeared. After cooling, the residue was treated with water, and the lead sulfate was collected in a filter crucible, dried, and weighed. Copper was determined by electrolysis in the filtrate from the separation of the lead, and from the small amount of lead dioxide collected on the anode and the previous weight of the lead sulfate, the total lead content was found. The filtrate from the separation of the lead and copper was evaporated to small volume and treated with ammonium hydroxide solution to precipitate the iron, the precipitate being collected, ignited, and weighed in the usual way. In the filtrate from the separation of the iron, nickel was precipitated with dimethylglyoxime and weighed in this form. The filtrate from the separation of the nickel was treated to remove organic matter and examined for the presence of zinc with phosphate, the results being negative except for one coin which contained a sufficient amount for quantitative determination. The coins were also examined for the presence of arsenic and sulfur, but the results were negative.

The procedure for the analysis of the bronze coins was similar except that the steps for the determination of gold and silver were omitted, neither being found in appreciable amount in any of the coins. Sulfur was found to be absent but arsenic was present in all but one. For the determination of the arsenic a sample was first dissolved in concentrated nitric acid, the solution was evaporated to dryness, and the residue was baked to decompose the nitrates. This baked residue was dissolved in concentrated hydrochloric acid, and the hydrochloric acid solution after adding ferrous sulfate, was distilled. In the distillate, properly diluted, the arsenic was precipitated as arsenious sulfide with hydrogen sulfide. This precipitate was collected in a filter crucible, washed first with water, next with carbon disulfide, and finally with ethyl alcohol, after which it was dried and weighed.

This is merely an outline of the methods of analysis, many necessary manipulative details being omitted for the sake of brevity. Where sufficient material was available, duplicate determinations were made. The closeness of most of the summations to 100%, as shown in the tables of results, is an indication, at least, of the generally satisfactory nature of these methods and of the experimental manipulation.

RESULTS OF MEASUREMENTS AND ANALYSES

The results of the specific gravity measurements are shown in Tables II, III, IV, and V. The calculated figures for silver content from specific gravity shown in the second column of each of these tables are based upon the assumption that the silver in the coins was alloyed only with copper. As shown by the chemical analyses (Table VI) this assumption is not correct, but copper is the usual and often the sole alloying metal in silver coins, and no other assumption appears possible in estimating the silver content of such coins from their specific gravities.

alone. In making the calculations the specific gravity of pure silver was taken as 10.50 and that of pure copper as 8.90. The formula used for the calculations was:

$$\% \text{ Silver} = \frac{S_1 S_x - S_1 S_2}{S_1 S_x - S_2 S_x} \cdot 100$$

Where, on the same temperature basis for each,

S_1 is the specific gravity of pure silver.

S_2 is the specific gravity of pure copper.

S_x is the specific gravity of a given coin.

This formula is based upon the ideal relationship between specific gravity and composition in a binary alloy in which no change in total volume of the com-

TABLE II
SPECIFIC GRAVITY AS AN INDEX OF SILVER CONTENT
GROUP I—UNTREATED COINS

Coin No.	Specific Gravity	Silver Content from Specific Gravity	Silver Content by Analysis	Difference
		%	%	%
1	10.29	88.5	94.2	-5.7
2	9.95	69.5	92.9	-23.4
3	10.09	77.5	90.6	-13.1
4	9.84	62.5	76.9	-14.4
5	9.66	51.5	74.3	-22.8
6	9.92	67.5	73.4	-5.9
7	9.59	47.0	67.9	-20.9
8	9.34	31.0	52.2	-21.2
				Ave. = -15.9

TABLE III
SPECIFIC GRAVITY AS AN INDEX OF SILVER CONTENT
GROUP II—ELECTROLYTICALLY CLEANED COINS

Coin No.	Specific Gravity	Silver Content from Specific Gravity	Silver Content by Analysis	Difference
		%	%	%
1	9.91	67.0	69.8	-2.8
2	9.73	56.0	58.2	-2.2
3	9.53	43.5	51.0	-7.5
4	9.48	40.0	47.3	-7.3
5	9.38	33.5	43.1	-9.6
6	9.42	36.0	41.8	-5.8
				Av. = -5.9

ponents occurs on alloying. Alloys of silver and copper fall in this class, and it has been shown experimentally that the silver content of modern coins may be closely approximated from their specific gravities.² No study appears to have been made before of the possibility of estimating the silver content of ancient coins from such measurements. If applicable, this method of estimation would be very useful since ancient silver coins are often of such rarity and value that chemical analysis is not practicable. However, because of the greater complexity of ancient

²Karmarsch, *Dinglers polytech. J.* 224, 565-573 (1877).

monetary silver and the possible presence of corrosion products on or in coins long buried in the ground, it might be expected that the method would be less certain than with modern coins.

Actually, as is shown in Tables II, III, IV, and V, large differences were found to exist between the silver content calculated from specific gravity and the silver content as determined afterwards by chemical analysis. These discrepancies are most marked in the results on the untreated coins (Table II). These low results can not be ascribed to any deposit of soil or to any crust of oxidation products of low specific gravity on the surfaces of the coins, as they were metallic in appearance and at the most were but slightly tarnished. It is likely that these coins, which

TABLE IV
SPECIFIC GRAVITY AS AN INDEX OF SILVER CONTENT
GROUP Ia—BLANKS OF UNTREATED COINS

Blank No.	Specific Gravity	Silver Content from Specific Gravity	Silver Content by Analysis	Difference
		%	%	%
1	10.35	92.0	94.2	-2.2
2	10.14	80.5	92.9	-12.4
3	10.18	82.5	90.6	-8.1
4	10.05	75.0	76.9	-1.9
5	10.06	75.5	74.3	+1.2
6	10.09	77.5	73.3	+4.2
7	9.85	63.5	67.9	-4.4
8	9.63	49.5	52.2	-2.7
				Av. = -3.3

TABLE V
SPECIFIC GRAVITY AS AN INDEX OF SILVER CONTENT
GROUP IIa—BLANKS OF CLEANED COINS

Blank No.	Specific Gravity	Silver Content from Specific Gravity	Silver Content by Analysis	Difference
		%	%	%
1	9.97	70.5	69.8	+0.7
2	9.86	64.0	58.2	+5.8
3	9.78	59.0	51.0	+8.0
4	9.64	50.5	47.3	+3.2
5	9.57	46.0	43.1	+2.9
6	9.52	42.5	41.8	+0.7
				Av. = +3.6

were obtained from dealers, had been cleaned mechanically. However, as is shown in Table IV, considerably better agreement was found between the calculated silver content and the actual silver content of the cleaned blanks of these same coins. This seems to indicate that the surface layers of the coins contained porous metal as the result of selective removal of base metal during burial in the ground or that these layers contained corrosion products of low specific gravity as a result of intergranular corrosion. As shown by the results in Table III much better agreement was found between the calculated and actual silver content of coins of the same type that had been cleaned electrolytically, especially for the two having the highest silver content. Apparently this cleaning procedure not only reduces visible surface oxidation products but reduces also the intergranular corrosion products below the surface, and in effect consolidates the metal. From Table V

it will be seen that for the blanks of the electrolytically cleaned coins the silver content as calculated from the specific gravity was found to be actually higher than that found by analysis, which is another indication of the internal consolidation of the metal by electrolytic cleaning. These higher results would be expected on compact metal of the composition found by analysis, by reason of the gold and lead present. All these results seem to show that the estimation of the silver content of untreated ancient coins from their specific gravities is a very unreliable procedure, but that useful rough results may possibly be obtained by measurement of the specific gravities of electrolytically cleaned coins. This whole question deserves extensive study.

The results of the chemical analyses of the coins are shown in Table VI. On comparing the percentages of silver given in this table with the figures for the fineness of Parthian drachms given in Table I some interesting similarities and differences are apparent. Both groups of results indicate that only in the early coins of this Parthian series is the silver content of the coins really high, and that in most later coins it falls considerably below this high standard. Though the figures of Table I indicate that it does not fall below 60%, the new results of Table VI shows clearly that it may fall nearly as low as 40%. These new results are in

TABLE VI
ANALYSES OF PARTHIAN SILVER COINS

Coin No.	Ag %	Au %	Cu %	Sn %	Pb %	Fe %	Ni %	Zn %	Total %
1	94.17	0.11	5.02	0.26	0.37	0.05	0.05	none	100.03
2	92.86	0.30	5.81	0.08	0.85	0.04	0.03	none	99.97
3	67.88	0.27	29.33	1.54	0.92	0.04	none	none	99.98
4	90.57	0.27	8.36	0.08	0.63	0.03	none	none	99.94
5	69.77	0.42	27.74	0.75	1.15	0.02	0.02	0.10	99.97
6	58.19	0.53	37.29	1.26	2.65	0.02	0.03	none	99.97
7	50.97	0.35	43.97	2.35	2.34	0.03	0.02	none	100.03
8	47.29	0.43	49.10	1.83	1.41	trace	0.03	none	100.09
9	43.10	0.33	52.26	2.64	1.51	0.05	0.04	none	99.93
10	41.84	0.34	51.92	3.44	2.48	0.04	0.02	none	100.08
11	76.87	0.38	21.75	0.34	0.64	0.04	none	none	100.02
12	74.30	0.27	24.42	0.27	0.54	0.07	none	none	99.87
13	73.33	0.35	24.16	1.36	0.86	0.01	none	none	100.07
14	52.05	0.21	44.52	1.16	1.41	none	0.03	none	99.38

ATTRIBUTIONS AND DATES

- Nos. 1 and 2. Mithradates I. 171-138 (?) B. C.
 No. 3. Sinatruces. 77-70 B. C.
 No. 4. Phraates III (?). 70-57 B. C.
 Nos. 5 to 10 inclusive. Orodes I. 57-38/37 B. C.
 No. 11. Gotarzes. 40/41-51 A. D.
 No. 12. Vardanes I. 41/42-45 A. D.
 No. 13. Volagases II. 77/78-146/147 A. D.
 No. 14. Volagases V. 207/208-221/222 (?) A. D.

direct contradiction to certain general statements that have been made in regard to the fineness of the Parthian silver coinage. For example, Burns³ states that the high initial standard continued with little alteration down to the end of the Parthian Empire in 227 A. D. However, as far as the present results show, the issue of really base silver drachms was confined to the reign of a single ruler, Orodes I of the period 57-38/37 B. C. It will be seen that in three of the six coins analyzed the silver content is below 50%. The average silver content of the six is only 51.69%. This is in marked contrast to the high silver content of 90.57% in a

³Burns, A. R. Money and monetary policy in early times. New York, 1927, p. 164.

coin (No. 4 of Table VI) of an immediate predecessor of Orodes I and to the generally high silver content of the coins of all his predecessors. Evidently a marked debasement of the silver coinage occurred during the reign of this ruler. The fact that the silver content of the coins of Orodes I is spread over a considerable range is not only a sign of debasement but is a sign of progressive debasement during his reign. It is obvious, as a general rule, that when no debasement occurs during the reign of a ruler his individual coins selected at random will not only be of high standard but will differ little from each other in fineness, but that if debasement of the coinage begins and continues during a reign such individual coins will differ considerably from each other in silver content. Some illustrative data are shown in Table VII. This table is derived from Tables I and VI, and shows the range of silver content and average silver content of all Parthian silver coins of which two or more of a given ruler have now been assayed or analyzed. It is not claimed that these figures are very reliable since so few individual coins of each ruler have been analyzed. The data based upon only two determinations are especially open to question. However, these are the only such figures possible at present, and they at least appear to give significant indications. It will be seen that the percentages of silver in the five coins of Mithradates I range over only 5%, whereas in the six coins of Orodes I they range over 28%. Then in the three coins of Gotarzes the range is again only 5%, with the coins of the other two rulers in intermediate positions. In the group as a whole a consistent inverse

TABLE VII
RANGE OF SILVER CONTENT AND AVERAGE SILVER CONTENT
OF COINS OF CERTAIN PARTHIAN RULERS

Ruler	Date	No. of Coins	Range in Silver Content %	Average Silver Content %
Mithradates I.....	171-138 (?) B. C.....	5	5.0	91.7
Artabanos II.....	88-77 B. C.....	2	12.6	79.1
Orodes I.....	57-38/37 B. C.....	6	28.0	51.7
Orodes II.....	4-6 A. D.....	2	17.6	71.0
Gotarzes.....	40/41-51 A. D.....	3	5.0	77.6

relationship exists between range and fineness. Apparently the debasement of the coinage during the reign of Orodes I was followed by considerable improvement during the reigns of the succeeding rulers, though the original high standard was never again restored.

The percentages of gold shown in Table VI are in approximate agreement with the fineness figures of Table I. In the analyses of Table VI the average percentage of gold is 0.33, and in the assays of Table I the average gold content in terms of percentage is 0.25. There is a greater discrepancy in the ratios of gold to silver in the results of the two tables, but this lack of exact agreement may be ascribed to the difference in the methods of determining the gold. It is likely that the present results are more accurate. As compared to those of modern silver, the proportions of gold in Parthian coinage silver are very high, but such proportions of gold are characteristic of ancient silver in general. The gold in the Parthian coinage silver was evidently present as a mere fortuitous impurity that accompanied the silver, and it varied considerably in proportion in accordance with the source of the silver and the details of its metallurgical treatment. It seems improbable that ancient metallurgists had any means of separating these small proportions of gold from silver, or that they were even aware that their silver contained gold in such proportions.

As the figures of Table VI show, copper is the main alloying component of Parthian coinage silver. That it was introduced into the alloy as the metal itself is very improbable as will appear from a consideration of the proportions of tin and lead in the coins.

Though the percentages of tin are not very high numerically, being above 3% in only one coin, they are nevertheless very high for ancient silver. They are generally higher in the debased silver coins of Orodes I than in the other coins that were analyzed, especially the earlier coins of high silver content. Tin, when not absent entirely, is usually present in ancient coinage silver to the extent of only a few hundredths or tenths of a percent. In a series of sixteen ancient Greek silver coins analyzed by Bibra,⁴ three were found to contain a trace of tin, the others none, and in a series of twenty-two Roman Imperial silver coins, many of them debased, which were analyzed by this same investigator, tin was either absent or present as a mere trace in eleven, the highest proportion found being

TABLE VIII
ANALYSES OF GREEK AND ROMAN SILVER COINS SIMILAR
TO THE COINS OF ORODES I IN FINENESS

Ag %	Au %	Cu %	Sn %	Pb %	Fe %	Ni %
73.96	0.25	23.94	none	1.35	trace	none
56.76	1.81	40.63	none	0.75	0.23	trace
54.92	0.15	43.80	0.20	0.75	0.11	0.07
43.97	0.10	55.26	0.21	0.31	trace	0.15
43.41	0.72	54.69	none	trace	0.97	0.21
40.66	0.17	58.70	0.10	0.13	0.24	none

TABLE IX
ANALYSES OF GREEK SILVER COINS OF VERY HIGH FINENESS

Ag %	Au %	Cu %	Pb %	Fe %	Ni %
99.40	trace	none	0.46	trace	none
99.19	0.34	none	0.13	trace	none
99.09	trace	none	0.40	trace	none
99.07	trace	trace	0.43	trace	none
98.98	0.003	none	0.63	trace	none

0.71% and the average only 0.13%. The analyses in Table VIII show his results on coins having about the same range of silver content as the coins of Orodes I. According to the analyses of Bibra, tin is likely to be absent especially from coins of very high silver content. This appears to be confirmed by some more recent analyses by Elam⁵ which are shown in Table IX. Apparently tin was absent from all these coins of very high fineness, or else the analyst did not think it worth while to determine the small amounts that could have been present. The absence of tin from all such coins is what might be expected from its usual absence from deposits of silver ores. In general, then, tin is not normally associated with the silver of ancient coinage alloys, and there is no reason to believe that the Parthian coinage alloys were exceptional in this respect. It seems very probable, therefore, that most of the tin in the Parthian alloys was introduced along with the copper.

⁴Bibra, E. von. *Ueber alte Eisen- und Silber-Funde*. Nürnberg and Leipzig, 1873, pp. 37, 40.

⁵Elam, C. F. *J. Inst. Metals* 45, 57-69 (1931).

Similarly, the percentages of lead shown in the analyses of Table VI, especially in the coins of Orodes I, are unusually high for ancient coinage silver, as may be seen by comparing these percentages with those shown in Tables VIII and IX. All these percentages are further compared in Table X, where it will be seen to what extent the proportions of lead in the coins of Orodes I are abnormally high. Evidently a fairly constant small proportion of lead is almost always present in ancient fine silver, apparently as a residue from the imperfect cupellation of argentiferous lead, but the proportions of lead in the debased coins of Orodes I are so abnormally high that it seems necessary to conclude that only part of this lead was introduced into the alloy along with the silver and that the rest was introduced along with the copper.

The small percentages of iron shown in the analyses of Table VI are probably without much significance, as iron is almost a universal accidental impurity in ancient metals and alloys. However, as shown by the analyses of Table IX, the iron content of ancient silver coins of very high fineness is usually very small, so that it might well be that the noticeably larger proportions found in these Parthian coins were introduced into the alloys along with the copper rather than with the

TABLE X

COMPARISON OF COINS OF ORODES I WITH EARLIER PARTHIAN COINS AND WITH CERTAIN GREEK AND ROMAN COINS IN RESPECT TO SILVER CONTENT, LEAD CONTENT, AND RATIO OF LEAD CONTENT TO SILVER CONTENT

GROUP	Ag %	Pb %	Ratio of Pb to Ag
Parthian Coins Prior to Orodes I.....	Max. = 94.17 Min. = 67.88 Av. = 86.37	Max. = 0.92 Min. = 0.37 Av. = 0.69	Max. = 0.014 Min. = 0.004 Av. = 0.008
Coins of Orodes I.....	Max. = 69.77 Min. = 41.84 Av. = 51.69	Max. = 2.65 Min. = 1.15 Av. = 1.92	Max. = 0.059 Min. = 0.016 Av. = 0.039
Greek and Roman Coins of Similar Fineness..	Max. = 73.96 Min. = 40.66 Av. = 52.28	Max. = 1.85 Min. = trace Av. = 0.63	Max. = 0.025 Min. = 0.000 Av. = 0.010
Greek Coins of Very High Fineness.....	Max. = 99.40 Min. = 98.98 Av. = 99.14	Max. = 0.63 Min. = 0.13 Av. = 0.41	Max. = 0.006 Min. = 0.001 Av. = 0.004

silver. It is still more likely that the small proportions of nickel shown in the analyses of Table VI were introduced with the copper rather than the silver. In these analyses nickel is invariably present in the coins of very high copper content (over 35%) but absent from more than half the others. Furthermore, the analyses cited in Table IX indicate that nickel is not normally associated with ancient silver, and this same lack of association is apparent from other analyses of ancient silver coins of high fineness. The small proportion of zinc found in one coin (No. 5) is in all probability a mere accidental impurity that was introduced along with the copper. Neither arsenic nor sulfur in weighable amounts was found in any of these silver coins.

The results of the analyses of the bronze coins are shown in Table XI. These are apparently the first analyses of any kind of a Parthian bronze object that have been reported. It will be seen that the two earliest coins are very similar to each other in composition, and that the two coins of Orodes I are also very similar to each other. Larger differences exist in the composition of the two coins of Sinatruces, but they are similar to each other in the proportions of lead they contain,

and their lead content clearly groups them together as distinctly different from the earlier and the later coins. These similarities in the composition of coins issued in the same reign seem to indicate the existence of at least some standardization and control in the preparation of the bronze coinage alloys.

Though these coins viewed as a whole are not very different in composition except in lead content, this one difference is very marked. The relationships of the proportions of the main components of the alloys to each other are perhaps more readily evident from the ratios of the percentages, shown in Table XII, than from the percentages themselves. For the coins of Sinatruces and of Orodes I these ratios were calculated from the average percentage figures for each pair of coins. It will be seen that in the two earliest coins the ratios of the components are essentially the same, and that in the group as a whole there is little change in the ratio

TABLE XI
ANALYSES OF PARTHIAN BRONZE COINS

No.	Cu %	Sn %	Pb %	Fe %	Ni %	As %	Total %
1	88.64	6.72	3.88	0.15	0.07	0.26	99.72
2	89.54	6.97	3.18	0.09	0.08	0.11	99.97
3	88.31	4.71	6.60	0.08	0.18	0.05	99.94
4	83.90	7.24	8.54	0.04	0.07	none	99.79
5	82.19	5.17	12.03	0.08	0.10	0.24	99.81
6	80.69	6.08	12.65	0.04	0.08	0.21	99.79

ATTRIBUTIONS AND DATES

No. 1. Mithradates I. 171-138 (?) B. C.

No. 2. Mithradates II. 123-88 B. C.

Nos. 3 and 4. Sinatruces. 77-70 B. C.

Nos. 5 and 6. Orodes I. 57-38/37 B. C.

TABLE XII
RATIOS OF MAIN COMPONENTS IN PARTHIAN BRONZE COINS

Period B. C.	Ratio of Sn to Cu	Ratio of Pb to Cu	Ratio of Pb to Sn
171-138 (?).....	0.08	0.04	0.6
123-88.....	0.08	0.04	0.5
77-70.....	0.07	0.09	1.3
57-38/37.....	0.07	0.15	2.2

of tin content to copper content. The most striking and significant fact is the progressive increase in the ratios of lead content to copper content and of lead content to tin content. This same sort of chronological change in these ratios, with the ratio of tin content to copper content remaining relatively constant, has been previously observed in various series of Greek bronze coins, and has been explained as being the result of the remelting of old worn bronze coins of previous issue with lead in order to obtain metal for the issue of new coins.⁶ However, the lead content of these Parthian coins is generally lower than that of contemporaneous bronze coins issued elsewhere in the ancient world, even in localities near Parthia. This is illustrated by the analyses listed in Table XIII of a series of coins struck in Syria.⁷ In this one respect, at least, Parthian bronze coins of the period covered by the analyses have a composition that is distinctive.

⁶Caley, E. R. *The Composition of Ancient Greek Bronze Coins*. Philadelphia, 1939.

⁷From Table XVIII, pp. 92-93, of the work cited in Reference 6.

The percentages of the various impurities listed in Table XI are similar to those generally found in ancient coinage bronze. The nickel content is noticeably higher than in most ancient coinage bronze of the same period, and this may be of some significance as a distinctive characteristic. Though there appears to be some systematic variation in the arsenic content from one reign to another, this is probably fortuitous, as the arsenic content of ancient coinage bronze, like the iron content, usually varies in an erratic manner, thus indicating that both are mere accidental impurities. Neither zinc nor sulfur, often present in ancient coinage bronze, was found in any of these Parthian coins.

THEORY OF DEBASEMENT OF THE DRACHMS OF ORODES I

In the preceding discussion of the analytical results it was shown that nearly all the tin, iron, nickel, and part of the lead, were introduced, in all probability, into the debased silver coins of Orodes I along with the copper. Such a mixture in the approximate proportions indicated by the analyses would constitute a bronze. Consequently, it may logically be inferred that the debased coinage silver of

TABLE XIII
ANALYSES OF SYRIAN BRONZE COINS

No.	Cu %	Sn %	Pb %	Fe %	Ni %	Zn %	As %	S %	Total %
1	88.72	8.54	2.56	0.11	0.04	none	0.04	0.02	100.03
2	90.80	6.52	2.25	0.29	0.02	none	0.02	0.01	99.91
3	80.12	6.18	13.12	0.01	0.03	0.05	0.26	0.17	99.94
4	80.84	5.94	11.84	0.01	0.07	0.03	1.32	none	100.05
5	64.32	4.07	31.70	0.01	none	none	trace	0.01	100.11
6	67.13	7.62	24.90	0.14	0.02	0.01	0.10	none	99.92

ATTRIBUTIONS AND DATES

- No. 1. Antiochus II. 261-246 B. C.
- No. 2. Antiochus III. 222-187 B. C.
- No. 3. Seleucus IV. 187-175 B. C.
- No. 4. Demetrius II. 146-138 B. C.
- No. 5. Antiochus VIII. 121 B. C.
- No. 6. Antiochus VIII. 114 B. C.

Orodes I was manufactured by alloying silver of good quality with bronze. Furthermore, the composition of this bronze could be calculated closely from the results of Table VI providing the composition of this silver were known. Though there seems to be no way to find out the exact composition of this silver, certain plausible assumptions as to its composition may be made. These are: A. That it was fine silver of the highest quality known in the ancient period, and that its composition was about the average of the analyses shown in Table IX. B. That it was Parthian coinage silver of high quality obtained by melting together worn coins of earlier reigns, and that its composition was about that of the average of the analyses of Coins 1, 2, and 4 of Table VI. C. That it was Parthian coinage silver of high quality produced mostly by melting down coins of the reign immediately preceding that of Orodes I, and that its composition was about that of Coin No. 4 of Table VI. In view of the usual practice in mints, assumptions B and C seem more likely than A, and possibly C is more likely than B. Shown in Table XIV are the results of calculations, based on these three assumptions, of the probable composition of the bronze used in producing the coinage alloy for each of the six coins of Orodes I. In making these calculations the gold was counted with the silver and no allowance was made for preferential loss of components of the bronze by

oxidation or volatilization during the melting of it with the silver. Actually, the calculated figures would not have differed materially if allowance had been made for various small losses that could have occurred in this way. It will be seen that the three sets of figures for each coin are similar to each other, in the proportions of the main components at least, regardless of which assumption is made as to the composition of the silver that was debased. Hence the exact composition of this silver is not a matter of great importance for estimating the essential composition of this bronze. In general, as shown by the closer absolute and relative correspondence of the figures based on the three assumptions, the greater the degree of debasement the less the importance of the exact composition

TABLE XIV

PROBABLE COMPOSITION OF THE BRONZE USED IN DEBASING THE COINS OF ORODES I CALCULATED ON THREE POSSIBLE ASSUMPTIONS AS TO THE COMPOSITION OF THE ALLOY THAT WAS DEBASED

Coin No.	Assumption	Cu %	Sn %	Pb %	Fe %	Ni %
5	A	94.63	2.55	2.68	0.07	0.07
	B	94.57	2.63	2.80	none	none
	C	93.98	3.03	2.90	none	0.09
6	A	90.93	3.07	5.88	0.05	0.07
	B	90.62	3.19	6.16	none	0.03
	C	90.16	3.42	6.33	none	0.09
7	A	90.66	4.85	4.39	0.06	0.04
	B	90.43	5.08	4.47	0.02	none
	C	90.10	5.28	4.55	0.02	0.05
8	A	94.11	3.51	2.32	none	0.06
	B	94.12	3.62	2.22	none	0.04
	C	93.91	3.76	2.27	none	0.06
9	A	92.79	4.69	2.36	0.09	0.07
	B	92.73	4.86	2.29	0.06	0.06
	C	92.54	4.98	2.32	0.08	0.08
10	A	89.94	5.96	4.00	0.07	0.03
	B	89.72	6.19	4.03	0.04	0.02
	C	89.49	6.33	4.08	0.06	0.04
All	Max.	94.63	6.33	6.33	0.09	0.09
	Min.	89.49	2.55	2.22	none	none
	Av.	91.97	4.28	3.67	0.03	0.05
9 and 10 only	Max.	92.79	6.33	4.08	0.09	0.08
	Min.	89.49	4.69	2.29	0.04	0.02
	Av.	91.20	5.50	3.18	0.07	0.05

of the silver. Though there are considerable differences in the calculated compositions of the bronze used in the manufacture of the alloys for the individual coins, these compositions viewed as a whole are not radically different. Because of the lesser importance of the exact composition of the silver, and the greater accuracy of the computations, especially as regards the figures for the minor components, the figures calculated for Coins 9 and 10 are probably more reliable than the others. The average figures for these two coins, shown at the bottom of Table XIV, may be taken as representative of the probable composition of the bronze that was used in producing the debased silver drachms of Orodes I.

The source of this bronze may have been earlier Parthian bronze coins. It seems significant that the average figures calculated for Coins 9 and 10 are similar to the analytical figures for the bronze coins of Mithradates I and Mithradates II given in Table XI. Bronze of the composition of the bronze coins of Orodes I, either in the form of the coins of this ruler or in the form of bulk metal, evidently was not used in producing his debased silver coins. Furthermore, it is improbable that bronze having the composition of the bronze coins of Sinatruces, or bronze coins of this ruler, could have been used for the purpose. Only one principal qualitative discrepancy exists between the calculated composition of the bronze used for debasing the silver coins of Orodes I and the analytical figures for the two early Parthian bronze coins. This is the presence of arsenic in these coins. However, it is entirely possible that the arsenic in the bronze coins was completely oxidized and volatilized on remelting and that as a consequence none was incorporated in the debased silver.

That bronze in the form of coins, rather than in any other form, was used in debasing silver for the production of the drachms of Orodes I is probable. It is the usual practice in mints to obtain most of the metal for the issue of new coins by melting down earlier ones, especially if these are worn, and at the time of Orodes I it is almost certain that most of the bronze coins of Mithradates I and Mithradates

TABLE XV

CORRELATION BETWEEN ANALYTICAL FIGURES ON COMPOSITION OF DEBASED SILVER COINS OF ORODES I AND THEORETICAL FIGURES

Coin No.	Source of Figures	Ag %	Au %	Cu %	Sn %	Pb %	Fe %	Ni %
9	Analysis.....	43.10	0.33	52.26	■ 64	1.51	0.05	0.04
	Calculation...	43.10	0.13	51.32	3.32	1.99	0.07	0.04
10	Analysis.....	41.84	0.34	51.92	3.44	2.48	0.04	0.02
	Calculation...	41.84	0.13	52.45	3.41	2.03	0.07	0.04

II still in circulation were in poor condition. Furthermore, the bronze coins of these two rulers are of larger diameter and greater weight than the bronze coins issued by later rulers, and this could have been an additional reason for withdrawing these particular coins from circulation and using them as a source of metal.

In Table XV are shown the results of calculations on the composition of the debased silver that could have been produced by melting bronze of the average composition of the coins of Mithradates I and Mithradates II with silver of the composition of Coin 4 of Table VI to produce alloys having the silver content of Coins 9 and 10 of Table VI. In making these calculations it was assumed that all the arsenic was volatilized from the bronze, and an allowance was made for a loss of 10% of the tin and lead by preferential oxidation in the process of remelting and alloying. The degree of debasement for Coin 9 is 52.41% and for Coin 10, 53.80%. It will be seen that there is substantial agreement between the actual and the theoretical figures. On the whole, therefore, it does not appear at all unlikely that the metal for the debased drachms of Orodes I was made by melting down silver coins of his immediate predecessor, or more than one predecessor, with early Parthian bronze coins.

On the basis of present knowledge, serious debasement in the long series of drachms issued by the rulers of Parthia occurred only during the reign of Orodes I. Though such causes as the dishonesty of mint officials, a series of internal economic crises, or the effect of monetary changes in other countries may account for this

debasement, no historical evidence in support of any such causes appears to exist. The real cause may have been military conflict between the Parthian and Roman empires, which not only first occurred during the reign of Orodes I but occurred repeatedly during his reign.⁸ Analogous conflicts, both in ancient and modern times, have often resulted in the debasement of the coins of at least one of the combatants. The prolonged warfare between the Parthians and the Romans during his reign may have led to a need for a greatly expanded coinage or have caused other economic changes that made debasement of the coinage a necessary consequence. Moreover, it seems significant in support of this as a fundamental cause that the end of this warfare coincided with the end of the reign of Orodes I and that after his reign there was an era of peace between the two empires that lasted nearly a century. If the debasement of the coins was caused directly or indirectly by this warfare, the rise in the fineness of the coins of the successors of Orodes I may plausibly be explained by the succeeding long period of peace. Though the Parthians were later engaged in other warfare with the Romans, and probably fought other peoples at various times, these other conflicts may not have been on such a scale as to affect seriously the economy of the Parthian Empire, and for that reason did not lead to the debasement of the coinage. Generally speaking, the debasement of a coinage is often an index of warfare so intense or prolonged that the economy of a country is seriously altered. In conclusion, therefore, it does not seem improbable that the fundamental cause of the debasement of the coins of Orodes I was the warfare known to have occurred between the Parthian Empire and the Roman Empire during the reign of this ruler.

⁸Sykes, Sir P. A History of Persia. London, 1930, Vol. I, pp. 346-359.

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HEALTH CONDITIONS IN THE MORAVIAN INDIAN MISSION OF SCHÖNBRUNN, IN THE 1770's¹

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In May, 1772, on a plateau above, and quite near to, the Tuscarawas River, in eastern Ohio, there was founded the Moravian Indian Mission of Schönbrunn by the well known Missionaries, David Zeisberger and John Heckewelder. They were accompanied and competently advised by the Rev. John Ettwein, a man with an unusual gift of organization. They had moved to the new mission site on the Tuscarawas from Langundo-Utenünk (*Friedensstadt*), a short-lived mission settlement on the Big Beaver, in northwestern Pennsylvania, at the express invitation of the Lenni Lenape king, Netawatwes, who desired to have the wholesome influence and example of a Moravian mission community as near as possible to its capital town of Gekelemukpechünk (Newcomerstown), where to his growing dismay the excessive use of liquor had been increasingly corrupting the physical and moral fibre of men and women alike.

Close to the beginning of the first of the Mission Diaries from Schönbrunn, such as were dispatched at regular intervals to the mother church, at Bethlehem, Pennsylvania, David Zeisberger remarks about a family of ten postulants for admission to the Moravian community that "in externals" they were "very poor, and sickly besides, as the Indians generally are when they come to us, until they have learned to live in a well regulated manner" (1). In part, the physical misery of this particular family may have been caused by the famine widespread, according to ample documentary evidence, among the Indians, in 1772. Zeisberger's remark, however, that the Indians, generally, were impoverished and sickly when they came to the Moravian missions, is obviously based on experience gained *prior* to his coming to Ohio, or he could not have known as yet that their condition improved, once that "they have learned to live in a well regulated manner;" that is, under Moravian mission discipline. After mentioning their lack of physical endurance in "agricultural or other manual labour," John Heckewelder (2) confirms Zeisberger's observation in the following words:

"Those who have been brought up to regular labour, like ourselves, become robust and strong and enjoy good health. Such was the case with the Christian Indians in the Moravian settlements."

This statement follows a paragraph in which he calls "the Indians . . . in general a strong race of men" capable of carrying record loads for hours and over great distances. The two examples, however, which he cites for it, suggest observations made in mission environment.

From the evidence cited, and from some more here not adduced, it appears that, to a great extent, the Indian population of the Moravian missions was made up of people who sought the missions in a condition of despondency, economical and physical rather than spiritual; yet, there are outstanding cases on record, in which the converts had been in no distress whatsoever, economical or otherwise. Since the rate of recovery, as a result of mission life, apparently was very high,

¹Paper read before the Anthropology Section of The Ohio Academy of Science at the annual meeting, in April, 1949, at Granville, Ohio. It reports part of the research work done by Dr. Mahr for The Ohio State Archaeological and Historical Society in connection with the restoration of the Moravian Mission town of Schönbrunn. The Society contemplates a detailed publication of these studies when completed.

there is good reason to assert that the Moravian mission atmosphere made for better health conditions than those in the surrounding heathen area. Zeisberger's and Heckewelder's mission diaries and other writings contain the data.

They also show that the locality of Schönbrunn was far from being a health resort; despite the excellent drinking water from the Beautiful Spring; despite its fertile soil; and despite its favorable geographic situation, in general. Whoever knows the Schönbrunn scene understands why it was badly infested with fevers. At the very foot of the Schönbrunn plateau there was the lagoon, a swampy meander loop of the Tuscarawas River. It was the ideal breeding place of a merry assortment of mosquitoes, including the genus *Anopheles* some species of which are notorious as the transmitters of certain types of malaria. In fact, the mosquitoes hatch, in the lagoon, even today, although the disease itself has disappeared for quite some time from the Tuscarawas and Muskingum valleys. In the 1770's, however, malaria was one of the scourges of both whites and Indians, at Schönbrunn; while Gnadenhütten, likewise founded in 1772 about ten miles downstream from Schönbrunn, but in a less swampy area, had little malaria. With the exception of one entry (Oct. 22, '73), the Gnadenhütten mission diaries, when referring to malaria, tell of repeated incidences, even of epidemic character at Schönbrunn; and so, of course, do the Schönbrunn diaries.

Zeisberger (3) writes about the mosquitoes at Schönbrunn that they "are found in woods in summer time in great numbers;" they "sting, and a night in the forest would be intolerable without the smoke of a fire. They are particularly annoying in changeable weather." Superfluous to say, this was written with no reference to malaria, the dependence of which on transmission by mosquitoes was not discovered until late in the 19th century. Up to that time, it was commonly held that the so-called miasmatic air in certain swampy regions, such as Schönbrunn, caused these fevers whose periodic incidence had long been known but could not be explained.

All malaria attacks recorded in the mission diaries fall within the months of July, August, September, and October. Under September 28, 1772 (4), Zeisberger writes, as follows:

"Many of our people [that is, Indian converts, *ACM*] have suffered attacks of fever, which is very common here at this time of the year."

1773 was an especially bad fever year. On August 18, 1773 (5), Br. Schmick, the Missionary at Gnadenhütten, makes this entry:

"[We] left by water for Schönbrunn, where we found Sr. Jungmann in bed suffering from chills and her husband still fagged out and weak from having had the same sickness."

Under August 19, he continues, as follows:

"... we visited the Brethren and Sisters [the converts] there [at Schönbrunn] in their houses and cabins and found many who had chills."

Still referring to Schönbrunn, Schmick writes, under September 21 (6): "Br. John Jungmann had another attack of fever;" and, on September 22:

"This evening, Br. Jungmann suffered an attack of chills. Bathseba [an Indian convert, *ACM*] prepared at once some *Beson* (usually a concoction made of herbs and/or roots) or medicine for him to drink, which he took gladly."

Br. and Sr. Jungmann, the Missionary couple at Schönbrunn, each had a very bad case of it.² Under September 30, 1775, Zeisberger made this entry in the Schönbrunn Diary (7):

²According to *SD* 5 (July 24, '73), Jungmann must have contracted the fever early in July, 1773. On September 1, he is reported to have "quite recovered from his fever"; a recovery, by the way, which did not last very long. In the same entry, the Diarist remarks that, "since yesterday," August 31, "his wife likewise has been in bed with fever."

" . . . Br. Jungmann, who has had fever for some time, has become worse and was obliged to take to his bed, . . . "

Zeisberger's entry of October 22, 1775 (8) contains the interesting statement, that

"Sr. Jungman . . . has for quite some time been suffering of three-day fever."

That clearly marks her case as a tertian malaria (*Plasmodium vivax*) in which the gametocytes erupt from the red corpuscles every 48 hours. Zeisberger adds that she "had severe pains in the side today," indicating that either her spleen or liver, or both, had become affected.

"After blood-letting," he concludes, "and application of medicinal remedies, she improved during the following days, the fever left her and she was quite restored."

Her husband's case, who, in 1773, is on record of having suffered attacks only one or two days apart (September 19, 21, 22), may have been a case of sub-tertian malaria (*Plasmodium falciparum*) characterized by more frequent, irregularly spaced attacks; or it may have been a case of a double infection, on two successive days, with *Pl. vivax*. Dr. Ernest Carroll Faust³) has expressed himself in support of this latter possibility, adding the following remark:

"Actually we know that under controlled conditions of experimental vivax infection in man there is at times a daily episode of chills and fever, the so-called 'malaria duplicata'."

Finally, there is a remote possibility of Jungmann's case having been a mixed infection: by *Pl. vivax*, causing tertian fever, and *Pl. malariae*, quartan fever; when overlapping, the result may be daily, or irregularly spaced, attacks such as in sub-tertian malaria. Dr. Faust states that *Pl. malariae*

"may have conceivably been present in the Muskingum Basin at that time, although the distribution of this malaria parasite in the Untied States within the last 50 years or more has been south of the Ohio River."

On the assumption that the mosquito population of the region has not substantially changed since the 1770's, there are two species of *Anopheles* to be considered as probable transmitting agents of malaria at that time: *Anopheles punctipennis* Say, and *A. quadrimaculatus* Say (Sa). Dr. Faust gives the following opinion:

"Although *Anopheles punctipennis* has been found infected in nature, it is much less anthropophilic than *A. quadrimaculatus*. Since the latter species has in recent years been present in Ohio, it is likely that it occurred in the same area in the 1770's. Therefore, it seems probable that the major part of malaria in those days may justly be attributed to the species *quadrimaculatus*."

According to Heckewelder (9), the aboriginal remedies applied in the treatment of "fevers" were, internally, emetics; and, externally, bleeding and sweating. There is ample evidence that the Moravian Missionaries freely and gladly made use of the medical lore of their converts, no less than did the Indians themselves, and with satisfactory results, at that. The Indian method of bleeding, such as practiced on Mrs. Jungmann, is described by Zeisberger (10), probably from personal experience, in the following words:

"For blood-letting they use flint or glass. Of either they break off little fragments until a piece is secured that suits the purpose. This is fixed to

³In a personal letter, of May 17, 1949, I have received invaluable information on this particular problem from Dr. Faust, The William Vincent Professor of Tropical Diseases and Hygiene, and Head of the Division of Parasitology, Department of Tropical Medicine and Public Health, in the School of Medicine, The Tulane University of Louisiana, at New Orleans. My sincere thanks go to Dr. Faust for his gracious assistance.—ACM.

a short stick, placed upon the artery and struck. In case of cupping, they open the skin with a knife, put a little calabash over the opening, burning birchbark instead of a lamp."

The Lenni Lenape's method of therapeutical sweating will be discussed below (p. 128).

The only step taken by Zeisberger and his Moravian associates toward combatting the fevers was a wise preventive measure. Under date of January 2, 1776, Zeisberger writes in the Schönbrunn Diary (11):

"Upon deliberation with the [Indian] helper Brethren, we resolved to lead water from the Muskingum [the Tuscarawas, *ACM*] into the little lake [the meander lagoon, *ACM*] near our spring, so that, in the summer time, we may not have stagnant water but a flowing stream beside our Town; which, as we hope, will not only be conducive to the health of the place but also bring various conveniences with it. We can do this without much trouble and labor if we dig a ditch about thirty rods in length. On the 4th [of January], the Brethren made a beginning, completing the task in a few days, as far as the water will now permit; the rest of the work must be left until warm weather comes."

If that had been done sooner, it might have prevented the hatching of millions of mosquitoes and, through it, many a case of malaria. As it was, the settlement could benefit from it for only fifteen months, since in April, 1777, under the duress of the Revolutionary War, Schönbrunn had to be abandoned, and was subsequently destroyed.

In regard to another serious endemic affliction of the Ohio Lenni Lenape, in the 1770's, namely, pulmonary tuberculosis, called *Schwindsucht* (consumption) in the mission diaries, the Schönbrunn Indian community appears to have fared very well. No more than two cases are on record in the Schönbrunn Diaries; both of them youths, who died at the Mission: the one (12), in 1773, had "been suffering from consumption for a year;" and the other (13) "was baptized," and "died December 10," 1775. "He came to us suffering from consumption," the diarist explains.

Heckewelder (14) offers the following aetiological comment:

"Consumptions are very frequent among them since they have become fond of spiritous liquors, and their young men in great numbers fall victims to that complaint. A person who resides among them may easily observe the frightful decrease of their numbers from one period of ten years to another."

These lines were obviously written many years after Heckewelder's sojourn at Schönbrunn; yet, as early as 1772, he had made his basic observations; in that same year, the Rev. David McClure (15) had occasion to witness an alcoholic orgy at Gekelemukpechünk, the Lenni Lenape capital.

Heckewelder correctly established an aetiological connection between alcoholic excesses and pulmonary tuberculosis, in that habitual drunkenness had obviously lowered the natives' physical resistance to tubercular infection, especially that of their young men, who were the principal offenders. Most likely, the two young TB victims who died at Schönbrunn had come to the Mission in their extreme despondency, seeking physical help as well as protection from further alcoholic temptations; for they knew that in the Moravian settlements "spiritous liquors" were not tolerated. Motivated by former experiences at their Mission town of Langundo-Utenünk, and by more recent ones at the newly founded Missions of Schönbrunn and Gnadenhütten, Zeisberger, Heckewelder, and Ettwein decided to enforce relentlessly the Mission statute prohibiting both the importation and the use of intoxicating liquor within the precincts of a Moravian settlement. The mission diaries record no infraction of this rule. In fact, the Moravian example

caused the Grand Council in Gekelmukpechünk, early in 1773, to pass a similar law for the heathen capital, which, on March 6, was most drastically enforced, according to the following entry in the Schönbrunn Diary (16):

"Two days ago, in Gekelemukpechünk, in pursuance of their resolutions, they had accomplished the first carrying into effect of their Acta, smashing ten barrels of rum for a trader and pouring out the contents on the ground, even before he came into their town."

Unfortunately, the good intentions of King Netawatwes' government were of a deplorably short duration. In Schönbrunn, however, the prohibition statute was all the more rigorously enforced. Under March 2, 1774, the Diary reads, as follows (17):

"We spoke with Indians who had come from Pittsburg, bringing rum with which to trade with the Indians, telling them that if they had such wares they should take another route, not passing through here. The same notice will be given traders who come here or pass through."

When, on April 6, 1775, drunken Indians arrived at Schönbrunn, with horse-loads of rum, their liquor was poured out; the Diary carries this comment (18):

"Thus we do with all Indians and white people, without respect of persons, who come into our Town or neighborhood with such wares. They may not use them as they please, so long as they are here; when they leave, they are accompanied to our borders."

Thus Schönbrunn was effectively protected against the plague of alcoholism, safeguarding, thereby, in great measure, its inhabitants' resistance to phthisic infection. Although, of course, the one or other case of pulmonary tuberculosis, in the community, may have remained undetected, yet the fact remains that the disease was definitely not endemic at Schönbrunn.

Another epidemic, however, although of an entirely different character, is mentioned in the Schönbrunn Diary, under date of July 17, 1773, as having attacked the children of the community. This entry, made in connection with the death of a four months old baby girl, reads, as follows:

"... A bad cough which has infested this entire region and, since the spring of the year, had taken a toll of 50 children in Gekelemukpechünk [the Lenni Lenape capital town, ACM] alone, has also spread among our own children, and only a very few have been spared."

The Gnadenhütten Diary, on August 10, 1773, concludes the report of a two-year old girl's death with the remark that "a blue cough accelerated her departure" [*"ein blauer Husten beförderte ihren Heimgang"*], indicating that Gnadenhütten, halfway between Gekelemukpechünk and Schönbrunn, likewise suffered from the cough epidemic. It is possible that this epidemic cough, with its numerous casualties, was an especially vicious incidence of whooping-cough; especially vicious, perhaps, because it may have attacked these Indians for the first time in their history. Yet it is also possible that it may have been a symptom of some other epidemic children's disease which, for lack of other symptoms recorded, cannot be identified. It is quite certain that the contagion was carried, to both Gnadenhütten and Schönbrunn, by visitors from the nearby heathen town so frequently mentioned in the diaries. From the Schönbrunn burial statistics, it seems more than likely that, apart from the one assured "cough" fatality, some more, if not all, of the nine infant deaths in 1773 had been caused by that epidemic.

Apart from what he called "pulmonary consumptions," Heckewelder (19) lists, as the principal "disorders to which the Indians are most commonly subjected, . . . fluxes, fevers and severe rheumatisms;" with the comment, that they are "all proceeding probably from the kind of life they lead, the hardships they undergo, and the nature of the food they take." In the light of present day

dietetics, their daily menu, mainly consisting of corn, beans, nuts, squashes, pumpkins, fresh and dried meat, fowl, fish, eggs of hens and turtles, various fruit, and even milk, buttermilk, and butter, maple sugar, and (very little) salt, constitutes an almost ideally varied and balanced diet such as cannot possibly be held responsible for the disorders listed above. In fact, on his very next page, Heckewelder makes the following statement (20):

"The gout, gravel, and scrofula or king's evil, are not known among the Indians. Nor have I ever known any one that had the disorder called *Rickets*."

Only one of these, scrofula, has nothing to do with nutrition; gravel, or kidney stones, may have a nutritional cause; but gout and rickets are definitely nutritional diseases. Their total absence, in any region, is sure proof of a highly adequate diet.

Heckewelder's term, "fluxes," means diarrhoeas of various origin. In the light of modern medicine, they are symptoms of diseases rather than diseases in themselves; mostly, of infectious diseases such as dysentery, and others.

The same is true for Heckewelder's "bilious fever" (21), which, in older medicine, was regarded as a disease in itself: *Febris biliosa*. Today, it is listed as one of the symptoms of a number of diseases, such as typhus, gall-stones, and other disorders of the liver and the bile duct. Zeisberger (22), in the Schönbrunn Diary, describes the case of a man "who had died . . . some time after" recovering from some ailment; "he experienced a chill, which ended in a yellow fever that continued for eleven days;" then he died. The eleven-day fever period makes it appear somewhat doubtful whether this was malaria (which frequently is attended by jaundice); or not rather a case of some other infectious disease involving the gall duct and liver. We are equally in the dark about what Heckewelder calls the "yellow vomit, which at times, carries off many of them. They generally die of this disease on the second or third day after the first attack" (23). In speaking of "bilious fevers" in general, he states (24)

"that these fevers generally make their first appearance in the season of the wild plum, a fruit that the Indians are particularly fond of. Sometimes also after a famine or long suffering for want of food, when they generally make too free an use of green maize, squashes and other watery vegetables."

Rather than cause these intestinal disturbances and the fevers attending them, the fruits and vegetables mentioned may have aggravated the patients' condition, especially when excessively used. It is well known today that most seasonal diseases are due to the prevalence, at the particular season, of their inciters. The principal cause of all these diarrhoeas and bilious disorders was doubtless the general sanitary situation in the Indian settlements. Zeisberger (25) has this to say:

"The brass kettles in which they cook, the dishes which they make of the growths and knots of trees, and also their spoons, which are usually very large, are rarely washed. . . . Yet in this respect, also, one finds differences, for some are as cleanly as one could expect it. The Monsys and the Mingoes, however, far excell the Delawares in uncleanness, and, since the dogs are in their houses or lying about the fires, there are universally many fleas and other insects."

As the Monsys, here mentioned, were a Lenni Lenape tribe living at the Big Beaver, the "Delawares," whom they excelled in uncleanness, apparently were the Lenni Lenape in the Muskingum area. What Zeisberger says about the dogs in the houses is clearly meant to have universal validity. It is uncertain, however, whether the following statement of Zeisberger (26), likewise applies to the Ohio Lenni Lenape:

"Sometimes they [the spoons] are only licked by the dogs in lieu of washing."

Although there is evidence (27) that the Missionaries and their wives tried to raise their converts' standards of cleanliness, it is uncertain to what extent such attempts were successful.

After calling the Indian bed, made up of "a mat with one or more deer or bear skins upon it, . . . a comfortable couch in summer time," Zeisberger (28) states that it "may be made very uncomfortable by the fleas brought in by dogs." At another place (29) he remarks that "bedbugs are to be found in the Indian huts at any time and fleas in the summer, not a few."

Such filthy conditions, favoring the spread of any kind of infection, were made considerably worse when a sick person was in the house, especially one with an infectious intestinal disease. Zeisberger (30) writes, as follows:

"Care and attention for the sick amount to but little, the Indians being poor nurses. So long as they can go out [to relieve themselves, *ACM*] they lie on the hard bed of boards; no longer able to do this they are laid on the ground near the fire [which is in the center of the house, *ACM*], possibly upon grass or hay, a small hole in the ground under the patient serving as a bed-pan."

No further comment is needed.

The worst scourge in the life of the inhabitants of Schönbrunn, Indian as well as white, next to malaria, was what both Zeisberger and Heckewelder call by the collective name of rheumatism. Heckewelder (31) states that "their old men are very subject to rheumatisms in the back and knees," while Zeisberger (32) remarks that "with advancing years" they commonly contract rheumatism, "often leading to lameness, deafness or blindness." It is evident that the term denotes symptoms of various diseases; symptoms of an arthritic nature, coupled with other symptoms. All these rheumatisms were invariably treated mainly by "bathing and sweating" (33). Heckewelder attests a successful sweat cure administered in the Lenni Lenape fashion to himself, when suffering from rheumatism (34), in September, 1772, at Schönbrunn (35). More about this later.

In connection with the matter of rheumatism, Heckewelder (36) makes the following remark which is of some significance for medical history, particularly of the Tuscarawas area where most of his observations were quite evidently made. He writes:

" . . . I have seen boys 10 and 12 years of age, who through colds or fits of sickness had become so contracted that they never afterwards recovered the use of their limbs."

What Heckewelder here describes is plainly Poliomyelitis; of especial significance is his aetiological, though erroneous comment: "through colds or fits of sickness;" for it has been observed that, frequently, a very early symptom of infantile paralysis is a 'running nose;' the "fits of sickness" evidently were such convulsions as are known to occur in the pre-paralytic stages of Poliomyelitis. It is likewise of importance that no epidemic incidence of the disease is described in the diaries of Schönbrunn or of any other Moravian Indian Mission in Ohio.

In an area in which both rattlesnakes and copperheads were frequent, occasionally people were bitten; yet deaths from snake bites were rare. Zeisberger (37) writes, as follows:

"Indians who have been bitten, even if they happen to be quite alone in the forest, know what to do. They seek certain herbs and roots that may be found anywhere and cure themselves of the bite, so that one rarely hears of a death occasioned by the bite of this serpent [rattlesnake]."

Apparently, the medical aid available in the Schönbrunn Mission community was adequate. It is certain that there was no white physician at, or even near, Schönbrunn; nor was there need for any. Both Heckewelder and Zeisberger attest that the Indians not only had competent professional practitioners of both sexes

with a sound knowledge of their native *materia medica*, but that there were also a great many non-professional men and women in possession of medical recipes, the composition of which they jealously guarded as valuable secrets. Besides, there were also, in every heathen community, "medicine men," who combined natural treatment of ailments with magic hokus-pokus. Of course, they were not to be consulted by the Mission populace. On the other hand, it is most likely that, in cases of emergency, the one or the other serious practitioner was called in from the heathen neighborhood. In most cases, though, the medical knowledge available among the Mission Indians seems to have sufficed. After criticizing the common Indian habit of dosing their patients excessively, Heckewelder makes this statement about native physicians (38):

"Nevertheless, I must say, that their practice in general succeeds pretty well. I have myself been benefited and cured by taking their emetics and their medicines in fevers, and by being sweated after their manner while labouring under a stubborn rheumatism. I have also known many, both whites and Indians, who have with the same success resorted to Indian physicians while labouring under diseases. The wives of the Missionaries, in every instance in which they had to apply to the female physicians, for the cure of complaints peculiar to their sex, experienced good results from their abilities. They are also well skilled in curing wounds and bruises. I once for two days and two nights, suffered the most excruciating pain from a felon or whitlow on one of my fingers, which deprived me entirely of sleep. I had recourse to an Indian woman, who in less than half an hour relieved me entirely by the simple application of a poultice made of the root of the common blue violet. . . . I firmly believe that there is no wound, unless it be absolutely mortal, or beyond the skill of our own good practitioners, which an Indian surgeon (I mean the best of them) will not succeed in healing."

The greatest asset of aboriginal, and particularly Lenni Lenape, therapy no doubt was the sweating-oven. Since Heckewelder was successfully "sweated after their manner" for rheumatism, in September, 1772 (39), the Mission Indians of Schönbrunn must have installed their local sweating-oven shortly upon the founding of their settlement; in fact, two of them, since the women had their own. These sweating-ovens were considered an indispensable necessity in every Indian settlement, from the Pacific to the Atlantic. Heckewelder (40) describes the Lenni Lenape sweating-oven, such as used by himself at Schönbrunn, as follows:

"The sweat oven is the first thing that an Indian has recourse to when he feels the least indisposed; it is the place to which the wearied traveler, hunter, or warrior looks for relief from the fatigues he has endured, the cold he has caught, or the restoration of his lost appetite. This oven is made of different sizes, so as to accommodate from two to six persons at a time, or according to the number of men in the village, so that they may be all successively served. It is generally built on a bank or slope, one half of it within and the other above ground. It is well covered on the top with split plank and earth, and has a door in front, where the ground is level, to go or rather creep in. Here, on the outside, stones, generally of about the size of a large turnip, are heated by one or more men appointed each day for that purpose. While the oven is heating, decoctions from roots of plants are prepared either by the person himself who intends to sweat, or by one of the men of the village, who boils a large kettleful for the general use, so that when the public crier going his rounds, calls out *Pimook!* "go to sweat!" every one brings his small kettle, which is filled for him with the potion, which at the same time serves him as a medicine, promotes a profuse perspiration, and quenches his thirst. As soon as a

sufficient number have come to the oven, a number of the hot stones are rolled into the middle of it, and the sweaters go in, seating themselves or rather squatting round those stones, and there they remain until the sweat ceases to flow; then they come out, throwing a blanket or two about them that they may not catch cold; in the meanwhile, fresh heated stones are thrown in for those who follow them. While they are in the oven, water is now and then poured on the hot stones to produce a steam, which they say increases the heat, and gives suppleness to their limbs and joints."

Then he continues with this phrase which clearly reflects a personal recollection of his sickness and its cure, in 1772:

"In rheumatic complaints, the steam is produced by a decoction of boiled roots, and the patient during the operation is well wrapped in blankets, to keep the cold air from him, and promote perspiration at the same time."

Heckewelder concludes his description with the following remarks:

"Those sweat ovens are generally at some distance from an Indian village, where wood and water are always at hand. The best order is preserved at those places. The women have their separate oven in a different direction from that of the men, and subjected to the same rules. The men generally sweat themselves once and sometimes twice a week; the women have no fixed day for this exercise, nor do they use it as often as the men."

The south slope of the Schönbrunn plateau, with the lagoon near by, "where wood and water are always at hand," answers to perfection Heckewelder's description of the locality of the sweating-oven for both men and women.

The Rev. David McClure who, in 1772, visited the Lenni Lenape capital of Gekelemukpechünk, where he saw a sweating-oven in operation, adds the significant information (41) that "to pulmonary disorders it is fatal, as also in the small pox."

Not a single case of this latter disease is recorded in the Schönbrunn Diaries or, so far as I know, in any of the diaries from the other Moravian missions in Ohio. That is quite astounding, in view of the past ravages of the disease in the East, on which McClure makes this comment: "This latter scourge of the human race has swept off multitudes of Indians from this continent."

With the Schönbrunn Lenni Lenape it may have been a matter of acquired immunity. A great many of them had come to Schönbrunn with the Moravians from Missions in Pennsylvania, some even from as far east as Bethlehem, and it is almost certain that they all had, once in the past, overcome the smallpox. Most likely, for the same reason, the white traders from the East, who regularly visited both the Missions and the heathen settlements in Ohio, were likewise immune; otherwise, fresh infections with smallpox would inevitably have occurred, at least among the children and younger people.

Zeisberger, Heckewelder, and McClure, in various instances, mention the sexual promiscuity and the alarming spread of Venereal Diseases among the Lenni Lenape. The Schönbrunn mission statutes successfully kept these moral and physical disorders out of the settlement by outlawing all offenders of either sex; and by insisting on the sacredness of the marriage bonds, which, in the heathen neighborhood, had long been scandalously ignored. The Schönbrunn Diaries fail to indicate to what extent previously infected converts, otherwise in good standing, contaminated their spouses and offspring. Yet it is reasonable to assume that numerous ailments of both adults and children, especially infants, could have been traced, in the light of modern diagnosis, to venereal infections.

The List of Burials in the Schönbrunn Cemetery, from 1772 to 1777 (42), provides the mortality figures for this period. In 1772, out of a total of 92 inhabitants, only one person, an infant girl, was buried. Fifteen people, including nine infants, out of a total of 184 souls, died in 1773. That is the only year for which the Mission Diary shows a direct correlation between the death rate and local health: 1773, as previously stated, was a bad malaria year, and also the year of the cough epidemic mentioned above (p. 125). In 1774, four persons, including two infants, were buried, of a population of 220. The mortality figure of 1775 is seven persons, among them three infants; the total population was 263. Out of an estimated total of over 300 people, in 1776, twelve were buried, including "five children," whose age is not given. In 1777, only one funeral is listed, in January; from then on, until April 19, when the Mission was abandoned, nobody seems to have died.

It is to be noted that the population of Schönbrunn increased, as substantially and steadily as it did, by immigration rather than by births. Moreover, the babies born were not so consistently recorded in the Mission Diaries as were those who had died. Yet it is evident that the mortality of infants was high: over one-half of all deaths, each year, were infants.

Referring, not to infants in particular, but to children in general, Heckewelder (43) states that "worms are a very common disorder among" them, and that "great numbers of them died from that cause. They eat a great deal of green corn when in the milk, with beans, squashes, melons, and the like; their bellies become remarkably large, and it is probably in that manner that the worms are generated."

Here again we have Heckewelder's frequent reversal of cause and effect; medical science knows that a distended and protruding abdomen, in a child, frequently indicates Hookworm infection (*Ancylostomiasis*), or the presence of *Ascarides* (*Ascariasis*), in which cases the vegetables and fruits, mentioned above, most likely made bad matters worse. Although Heckewelder's observations were made with no particular reference to Schönbrunn, yet they may be safely applied not only to Schönbrunn but also to the other Moravian mission settlements, as well as to the pagan communities of the area. The same is true for *Trichinosis*. Heckewelder (44) tells a story which makes it evident that the pigs were left at liberty to roam in the forest. When an infected pig was eaten by a bear, or died and was eaten by another pig, the people who ate of that bear's or other pig's flesh were most likely to contract *Trichinosis*. The general Indian habit, however, of cooking their meats and fish "so thoroughly . . . that they fall apart," as stated by Zeisberger (45), may have substantially curbed the incidence of *Trichinosis*, although it probably did not prevent it entirely.

All available evidence points to it that the health conditions, in the Moravian Mission town of Schönbrunn, during the five years of its existence, were as good as could be expected in the close proximity to a malaria swamp; and in the almost total absence of such sanitary measures as are today considered the minimum requirement for healthy living, even in a primitive environment. Had not Schönbrunn enjoyed the ample and excellent drinking water from the Beautiful Spring that lent it its name, the health conditions of the place probably would have been even much worse. True, the preventive measures taken, in many respects, by the Mission authorities, helped to establish certain rudiments of hygiene and principles of moral conduct, that no doubt made their converts better men and women than were their pagan neighbors. Yet it is equally apparent that, without the recourse which the Missionaries and their families were incessantly forced to take to the aboriginal resources of the wilderness, and to the age-old experience and medical lore of their native charges, they would have been hopelessly lost.

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With abbreviations used in the Notes

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NOTES

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| (1) SD 1, June 28, '72 | 24) <i>ibid.</i> |
| (2) HH, p. 220 | (25) ZH, p. 16 |
| (3) ZH, p. 75 | (26) ZH, p. 86 |
| (4) SD 2, Sep. 28, '72 | (27) GnD, June 29, '73; SD 10, Apr. 27, '75;
SD 12, Jan. 15, '76 |
| (5) GnD, Aug. 18, '73 | (28) ZH, p. 86 |
| (6) GnD, Sep. 21, '73 | (29) ZH, p. 75 |
| (7) SD 12, Sep. 30, '75 | (30) ZH, p. 24 |
| (8) SD 12, Oct. 22, '75 | (31) HH, p. 222 |
| (8a) MMNO, p. 13 f. | (32) ZH, p. 24 |
| (9) HH, p. 224 f. | (33) ZH, p. 55 |
| (10) ZH, p. 27 | (34) HH, p. 229 |
| (11) SD 12, Jan. 2, '76 | (35) SD 2, Sep. 28, '72 |
| (12) SD 5, July 2, '73 | (36) HH, p. 222 |
| (13) SD 12, Dec. 7, '75 | (37) ZH, p. 222 |
| (14) HH, p. 223 | (38) HH, p. 229 |
| (15) McCd, pp. 71-78 | (39) SD 2, Sept. 11, '72 |
| (16) SD 3, Mar. 8, '73 | (40) HH, p. 225 |
| (17) SD 7, Mar. 2, '74 | (41) McCd, p. 67 |
| (18) SD 10, Apr. 6, '75 | (42) ms. MAB |
| (19) HH, p. 222 | (43) HH, p. 222 |
| (20) HH, p. 223 | (44) HH, p. 147 |
| (21) HH, p. 222 | (45) ZH, p. 14 |
| (22) SD 5, Sep. 5, '73 | |
| (23) HH, p. 222 | |

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NUMBERS AND SUCCESS

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It is easy to remove passages from a general discussion and attribute to them a meaning they were not intended to have. Also, in a long discussion, statements may be made so far from expressions of the central concept that their significance is overlooked.

Presumably in one of these ways Dr. McAtee (1949) in this journal has misapplied some remarks of mine (Shull, 1936) concerning the road to success in evolution. After quoting part of an account of the way in which natural selection was at first supposed to work through life-and-death distinctions, he portrays my substitute for that method as dependent on the thesis that "success or failure depends on numbers," and that "numbers . . . constitute the best assurance of permanence." He then proceeds to apply this concept to species. His reader no doubt compares the number of grizzly bears with the number of flies that annoy them, and concludes that if the numbers of individuals were equal the bears could be fairly happy—irrespective of their chances of survival as compared with the insects. Man with his two billion or so should be in no danger—unless, as some people fear, from himself; but a bacterial species made up of only two billion individuals might well be on the verge of extinction. No one could seriously maintain that numbers of individuals, without reference to the kind of organism, would be a good measure of success or a good insurance policy.

To understand the wrong application here, one must remember that the book quoted was the first *general* work on evolution to emphasize the genetic factors. The early chapters dealt with the traditional arguments about evidences of evolution; but long before page 152, from which McAtee quotes, the genetic groundwork was laid and the evolutionary operation of the genetic mechanism was described. A species was best described as possessing various alternative genes in certain frequencies—68 per cent of A , 19 per cent of a , and 13 per cent of a' , and so on for all the loci of genes in the chromosomes. The frequency of one of these genes would change from generation to generation, and such changes would be evolution. Even if they never led to a change of phenotype which a taxonomist would dignify by calling a new species, the change of frequency of alternative genes was really evolution. Much evolution has been lost, but it was evolution. The bulk of evolution has been effected by such changes of frequency of genes.

When gene A first mutates to a , the latter gene is rare. Accordingly, it may be lost. But to be lost, the individual that contains it must be lost or its germ cells fail to contribute to new individuals. If gene a is to increase in frequency, the individuals that contain it must leave relatively more descendants than do those containing only A . Whether more descendants are to be had by good luck, or only by possessing some advantage associated with gene a , is immaterial; increase of the frequency of the new gene requires increase of the individuals carrying it. Such increase of individuals could be arrived at by further mutations of A to a . If A mutates to a often enough, and there is no opposing factor, gene a gradually replaces A . The whole species could eventually be made to possess gene a , to the exclusion of A , merely by repeated mutations to a . All this would involve, of course, getting more and more individuals carrying the new gene.

The import of "numbers of individuals" should now be clear. Numbers of elephants are not being contrasted with numbers of mice. No species is contrasted with another species. It is numbers of individuals carrying gene a instead of A , or carrying gene m instead of M or m' , that matters. If gene b is to succeed in evolution, at the expense of b' or B , that success can be attained only by increasing the number of individuals possessing b . An effective way of getting an increase of such individuals, after the new gene comes to expression, is for it to possess an advantage over the old gene. This advantage must be one that leads its possessor to produce more descendants. A new gene that makes the life of its possessor more comfortable, but does not increase its descendants, is not advantageous in the evolutionary sense. Such a gene, if it succeeded in becoming permanent, would owe that success to some other factor than selection; but whatever that factor were, it would have to operate by increasing the number of individuals possessing the new gene.

The paragraphs containing the passages quoted by McAtee contain nothing to indicate that it is success of species in relation to other species that is insured by numbers of individuals. Not even the page, nor the chapter, nor the whole book gives any expression to that idea. Everywhere it is characters, more directly the genes, whose permanence is made more probable by numbers of individuals. Though the words "class" and "type" are used, in no part of the discussion do they have a taxonomic meaning. The "class" of individuals possessing a certain gene is contrasted with another "class" or "type" having one of the alternative genes at the same locus. The reader should have no difficulty in seeing that the words have that meaning. If one of these "classes" has more descendants, its genetic basis becomes more prevalent—is more successful. It would be unfortunate to have the genetic argument used in support of mere numbers as a measure of success of species, particularly of unrelated or only distantly related species.

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A DESCRIPTION OF WARNER'S HOLLOW

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It is the purpose of this report to describe an area in Ohio of great natural beauty with which it is believed that very few people are familiar. The Hollow is quite inconspicuous when passed from a distance on the main route and this circumstance alone has largely contributed to its isolation. In spite of the fact that a 4H camp has been erected upon the southwest rim of the region, very little attention has been attracted to the Hollow, scientific attention in particular.

The author feels that biological potentialities of Warner's Hollow are enormous. This area would very probably make an interesting ecological study.

Warner's Hollow is situated in the extreme southwestern portion of Ashtabula County and near the town of Windsor. As shown in Fig. 1, the Hollow can be reached on routes 534 (south from Geneva-on-the-Lake) and 322 (east from Cleveland) as both roads pass through Windsor.

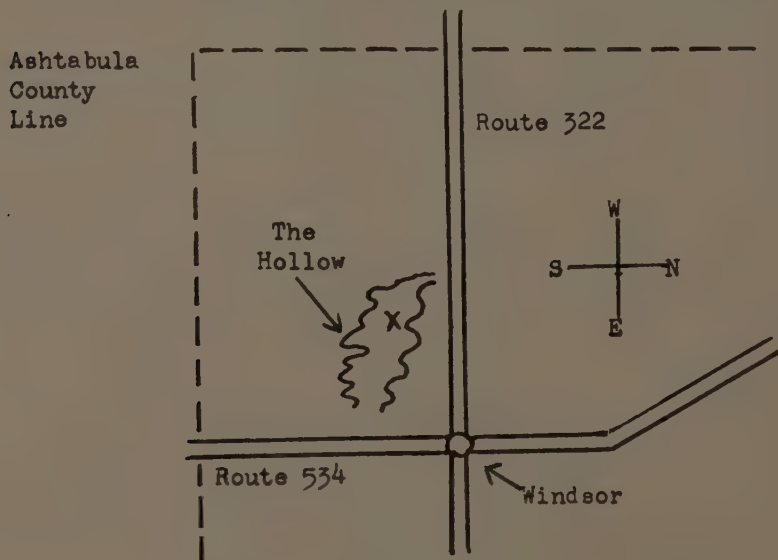


FIG. 1

The region extends lengthwise in an east and west plane. The floor of the Hollow is quite convoluted, the distance along the bottom from end to end being approximately two miles. At its widest place the Hollow is roughly 1200 feet and its narrowest about 20 feet, the distance being estimated from the top of the north wall to the top of the south wall.

The Hollow is a glacier and river worn gorge which opens sharply in the midst of gently rolling landscape that characterizes this portion of northeastern Ohio.

A stream flows from west to east along the floor of the gorge. The stream is called Phelps Creek and is a tributary of the Grand River. The Creek is spring-

fed while in the Hollow and is quite shallow except for occasional pot holes of depth from six inches to six feet. One spring of very fine cold water is located on the north wall and may be readily reached by means of a foot path which winds along the cliff.

According to Mr. Tom White, who owns a considerable portion, it is believed that a part of the area was once an Indian fort. Arrowheads and similar relics have been found in and around the gorge.

The rock content of the Hollow is predominantly sandstone, shale, and some limestone. Fossil shells of mollusks have been found in the sandstone of the south wall, Pelecypod shells mostly represented.

A considerable portion of the gorge walls are bare rock and either sheer or jutting and sometimes both. The highest point of the Hollow above the stream is located on the south wall and is roughly 110 feet in height.

Imprints of fossil leaves and tree bark have been observed on the rocks in the bottom of the gorge near the creek.

An isolated formation called table rock is found rising from the floor of the Hollow and is roughly 45 feet in height. This structure was apparently dislodged by a previous rockfall possibly caused by extensive undermining of the north wall by river erosion. The rock top is quite flat and covers about 600 square feet. It is tilted somewhat toward the north. Although in recent years the top of table rock has been somewhat defaced by campers, there are still visible near the south edge and overlooking the stream, a pair of footprints of a girl's bare feet. Popular legend as related by several natives claims that, "once an Indian maiden, pursued by two male Indians with dire intent, stood finally upon this spot while the earth here was yet soft and debated whether or not to jump." Also according to popular legend she jumped and so it goes on to state, "the footprints have remained to this day." Actually, one of the local dwellers was an amateur sculptor, who, using his daughter as a model, chiseled the footprints in the rock surface. Opening near the base of table rock are several small openings about six inches in diameter which lead inside to a chamber known as Barometer Cave, so called because of the response of its air currents in relation to weather fluctuations.

Winding along the walls on both sides are narrow footpaths, some located beneath far-jutting rocks. These paths are largely the result of natural conditions.

Warner's Hollow is an abrupt change from the surrounding landscape, not only from a geological standpoint but also that it is characteristic of a Canadian Life Zone.

Considerable stands of Native Hemlock are present as well as Mountain Maple. Ground Yew is well represented. Lichens are very numerous. The Bryophytes are plentiful. Liverworts and various types of mosses thriving in shady nooks and on the dripping wet rock walls, other types of mosses on the woody summits of the walls are also plentiful.

The Pteridophytes are well represented, there being several different kinds of ferns and Equisetinae. The Club mosses are especially abundant, being found in the rich shade of bottom land and upper woodland in the immediate vicinity of ground Yew.

The animal life is quite similar to the surrounding countryside with the possible exception of the Newts and Salamanders. The Caudata are represented here by *Triturus viridescens* (most numerous), *Plethodon jordani*, and *Eurycea lucifuga*. These forms of the Caudata are so plentiful that they may be observed crawling about in the wooded areas and among the rocky ledges of the Hollow all day long.

The Author wishes to express most sincere appreciation for the aid given in this endeavor by the Junior 4H Group of Ashtabula County and also hopes that some curiosity has been incited by this paper so that Warner's Hollow may receive more of the attention which it deserves.

STUDIES ON FRESH-WATER BRYOZOA, XVII. MICHIGAN BRYOZOA

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INTRODUCTION

The purpose of the present study is to record the occurrence of several bryozoan species from localities new to Michigan and other regions; to compile a list of the bryozoa previously recorded from Michigan; and to correct or revise the identification of some of the species collected long ago.

Records published by various writers from 1882 through 1949 have reported the following bryozoa from different Michigan localities, sometimes under synonyms or outmoded names:

Class ECTOPROCTA

Order GYMNOLEAEMATA

Family Paludicellidae

1. *Paludicella articulata* (Ehrenberg) 1831

ORDER PHYLACTOLEAEMATA

Family Cristatellidae

2. *Cristatella mucedo* Cuvier 1798

Family Fredericellidae

3. *Fredericella sultana* (Blumenbach) 1779

Family Lophopodidae

4. *Pectinatella magnifica* Leidy 1851

Family Plumatellidae

5. *Hyalinella punctata* (Hancock) 1850
6. *Plumatella casmiana* Oka 1907
7. *Plumatella orbisperma* Kellicott 1882
8. *Plumatella repens* (Linnaeus) 1758
9. *Plumatella repens* var. *coralloides* (Allman) 1850
10. *Plumatella repens* var. *emarginata* (Allman) 1844
11. *Stoella indica* Annandale 1909

The recorded localities for the above list of bryozoa are named in Table I. The sixteen references from which the Table was compiled are on file with both authors and are not here reproduced.

To the above listed species the present study adds the following two new Michigan records:

Class ECTOPROCTA

Family Plumatellidae

- Plumatella repens* var. *jugalis* (Allman) 1850

Class ENTOPROCTA

Family Urnatellidae

- Urnatella gracilis* Leidy 1851

In addition to the *Urnatella gracilis* and the *Plumatella repens jugalis* three other bryozoa (*Paludicella articulata*, *Plumatella casmiana* and *Plumatella repens* var. *emarginata*) were found in new localities in the present study collections. Their distribution is given in Table II.

TABLE I

PREVIOUSLY RECORDED MICHIGAN COLLECTION SITES WITH ASSOCIATED COLLECTORS AND BRYOZOA

[illegible]

TABLE II
PRESENT STUDY COLLECTION SITES AND ASSOCIATED BRYOZOA

State	Michigan Sites					Indiana		Pennsyl- vania	Utah
Station.....	558	565	566	567	568	611	613	612	614
<i>Urnatella gracilis</i>		x	x	x	x		x		
<i>Paludicella articulata</i>	x	x	x	x	x	x	x		
<i>Plumatella casmiana</i>	x						x		
<i>Plumatella repens</i> var. <i>jugalis</i>	x								
<i>Plumatella repens</i> var. <i>emarginata</i>	x		x	x	x		x	x	x

TABLE III
MEASUREMENTS OF PRESENT STUDY STATOBLASTS

	<i>Plumatella casmiana</i> *	<i>Plumatella repens</i> var. <i>emarginata</i>
Floatoblasts		
a. Total length	.0346-.360 mm.	.0432 mm.
b. Total width	.216-.245	.230
c. Capsule length	.245-.266	.281
d. Capsule width	.187-.202	.206
e. Dorsal side		
1. Float length	.086	.144
2. Float width	.043-.050	.07
f. Ventral side		
1. Float length	.058	.115
2. Float width	.029-.036	.022
Sessoblasts		
a. Total length	.461-.475	.461-.468
b. Total width	.360-.367	.346-.389
c. Capsule length	.410-.418	.403
d. Capsule width	.302-.317	.288-.346
e. Float width	.029	.029-.036

*The *Plumatella casmiana* floatoblasts here measured are of the ordinary type which is shown in Figures 8 and 9 and not of the other type which is shown in Figures 10 and 11.

COLLECTION DATA

The material for the present study was collected within recent years from Michigan, Indiana, Pennsylvania and Utah. It consists of nine batches or samples of material numbered 558, 565, 566, 567, 568, 611, 612, 613 and 614. Strictly speaking, this study should have included only the Michigan samples #558, 565, 566, 567 and 568, but rather than prepare a separate paper for the other four samples from Indiana, Pennsylvania and Utah, it was decided to include them in the same paper with the Michigan specimens.

Sample #558 was collected by H. van der Schalie on July 18, 1945, in Lake Erie at Pte. Moullie, near the mouth of the Huron River, Monroe County, Michigan. It contained *Paludicella articulata*, *Plumatella casmiana* and scraps of *Plumatella repens jugalis*.

Sample #565 was collected by H. van der Schalie on September 6, 1945, near the railroad bridge one mile above Ionia, in Grand River, Ionia County, Michigan. It consisted of several empty mussel shells heavily encrusted with a thick mat of *Paludicella articulata*. Some showed germinated hibernacula, as well as stalks of *Urnatella gracilis*.

Sample #566 was collected by H. van der Schalie on September 4, 1945, from the Grand River, near Ionia, Ionia County, Michigan. It consisted of bivalves to which were adhering sessoblasts of *Plumatella repens emarginata*, old *Paludicella articulata* hibernacula and a few *Urnatella* stalks.

Sample #567 was collected by H. van der Schalie on September 5, 1945, from the Grand River below Lyons, Ionia County, Michigan. It consisted of bivalves on which were growing dense clumps of *Plumatella repens emarginata*, a few sprigs of *Urnatella* and *Paludicella articulata* colonies and hibernacula.

Sample #568 was collected by H. van der Schalie on September 6, 1945, from Grand River below the Dexter Street Bridge at Ionia, Michigan. It consisted on bivalves overgrown with *Paludicella* colonies and hibernacula, *Urnatella* stalks and some *Plumatella repens emarginata* statoblasts.

Sample #611 was collected by H. van der Schalie on August 31, 1948, at Station 11 in Pigeon Creek just east of Flint, Jackson Township, Steuben County, Indiana. It consisted of mussel shells, tiny rock fragments, pieces of broken glass and other debris, moderately covered with *Paludicella articulata* colonies and hibernacula.

Sample #612 was collected by H. van der Schalie and Harold W. Harry on August 27, 1948, at Station 4 in Traverse Creek, a western branch of Racoon Creek, west of Clinton, Pennsylvania, near U. S. Highway #30. It consisted of rock and mussel scrapings and some *Plumatella repens emarginata* statoblasts.

Sample #613 was collected by Carl D. Riggs on August 7, 1946, from Tippecanoe River, seven miles below Pulaski, Pulaski County, Indiana. It consisted of mussel shells encrusted with *Urnatella gracilis*, *Paludicella articulata* and *Plumatella casmiana*.

Sample #614 was collected by H. van der Schalie and Elmer G. Berry on June 16, 1934, from Nibley Park Stream at Salt Lake City, Utah, and contained *Plumatella repens emarginata* scrapings.

The five bryozoan species from the above samples are listed in Table II and are discussed in more detail in the following section.

DISCUSSION

Urnatella gracilis

Urnatella gracilis is a colonial form consisting of one to six beaded or segmented stalks arising from a basal plate. The stalks are tipped by a calyx or head and may have additional short branches and calyces arising from the main beaded stalk. Sometimes there is a cluster of such small branches near the distal tip of the stalk. Other times there are sparse branches arising from several regions along

the stalk. Bracket or handle-like structures on the stalk indicate the bases of broken off branches (see Fig. 16).

The number of segments in the stalk varies from one to eighteen. Those nearest the basal plate are conspicuously urn-shaped (see Fig. 14); those more distal are more bead-like, softer in texture and lighter or paler in color. The basal segments are usually deeply colored (amber, brown or black), depending upon age. The deepest coloration is in the constricted region of each segment. A dark perforated septum incompletely separates successive segments. Davenport (1893, p. 7) found the top septum which separates the calyx from the stalk to be somewhat more complex than the other septa. He also reported seeing flame cells and yolk granules in the stalk.

Each stalk terminates in a calyx. These calyces or heads may drop off and new ones may regenerate from the stalk tip, apparently as in *Barentsia laxa* and related species. The calyx is rimmed by 8 to 16 tentacles which are not retractile but roll inward, as in other Entoprocts (see Rogick, 1948, *Barentsia laxa* figures, especially Figs. 15, 17, 19, 20, 22, 24 and 33). The internal anatomy of the calyx, as described in Davenport's 1893 paper, appears to be similar to that of *Barentsia laxa*. Davenport (p. 15) was able to find only adult male zooids so could not study the sexual reproduction of *Urnatella* or the anatomy of female specimens, so that is one of the problems remaining for some future worker.

Richardson (1921, p. 442) reported *Urnatella* as feeding on diatoms.

The present specimens were collected in Grand River, Ionia County, Michigan, and in Tippecanoe River near Pulaski, Indiana, see Table II.

The known distribution records for this as yet exclusively American bryozoan are as follows: Leidy found *Urnatella gracilis* on a number of occasions between 1851 (p. 322) and 1884 (pp. 5-6) around Philadelphia, in the Schuylkill River, below Fairmount dam, on the underside of stones, shells, on eel grass *Vallisneria spiralis* and on water star grass *Schollera graminea*. His friend, Dr. Isaac Lea, showed him a *Unio* shell from the Scioto River in Ohio on which were some *Urnatella* remains. Davenport (1893, p. 2) and Potts in 1892 collected *Urnatella* in great quantities from the turbulent waters immediately below the overflow of

EXPLANATION OF PLATE I

All figures were drawn from preserved material with the aid of a camera lucida.

FIG. 1. An old *Plumatella repens* var. *emarginata* sessoblast. The free surface of its large dark capsule is roughened by slightly raised ridges. Drawn to Scale A.

FIG. 2. A younger *Plumatella repens* var. *emarginata* sessoblast. Dissected out of the same colony as floatoblasts on Figures 3 and 4. Drawn to Scale A.

FIG. 3. The dorsal surface of a *Plumatella repens* var. *emarginata* floatoblast, showing the dark capsule about half covered by the float. Drawn to Scale A.

FIG. 4. The ventral surface of a *Plumatella repens* var. *emarginata* floatoblast showing the lesser encroachment of the float upon the capsule. Drawn to Scale A.

FIG. 5. Edge view of *Plumatella repens* var. *emarginata* floatoblast, showing the flat dorsal face and curved ventral face. The statoblast is resting on its dorsal face in this figure. Drawn to Scale A.

FIG. 6. A sessoblast of *Plumatella casmiana*. It closely resembles those of *P. repens* var. *emarginata*. Drawn to Scale A.

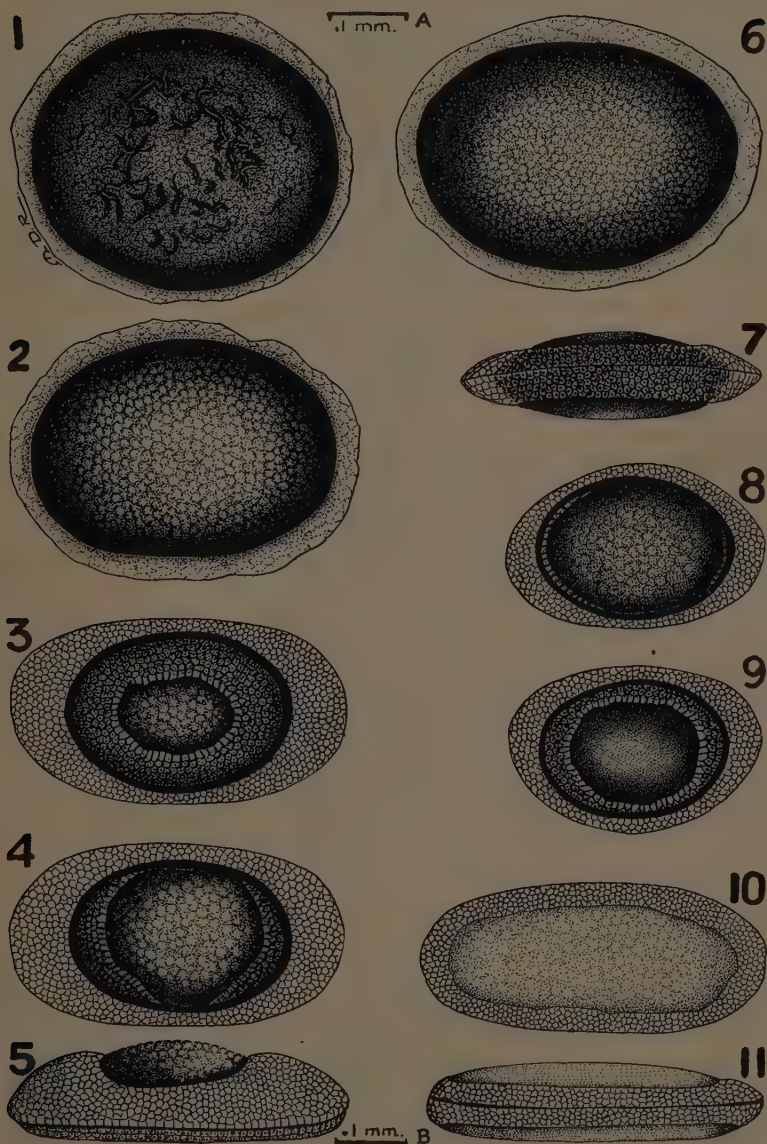
FIG. 7. Edge view of one type of *Plumatella casmiana* floatoblast. Adapted from Study XIII, p. 267, Fig. 7 (Rogick, 1943).

FIG. 8. Ventral face of a *Plumatella casmiana* floatoblast of the same type as the preceding. Drawn to Scale A.

FIG. 9. The dorsal face of a *Plumatella casmiana* floatoblast of the same type as the preceding. Drawn to Scale A.

FIG. 10. Face view of the second, distinctive, thin-walled type of floatoblast of *Plumatella casmiana*. Drawn to Scale B.

FIG. 11. Edge view of the same type of *Plumatella casmiana* floatoblast as the preceding. Drawn to Scale B. Adapted from Study X, p. 213, Fig. 3 (Rogick, 1941).



the Flat Rock Dam in the Schuylkill Canal near Shawmont Station, Pennsylvania. It covered almost every stone. Kofoed (1898, p. 402) found *Urnatella* at Havana, in the Illinois River near the Illinois Biological Station and in 1908 (p. 290) in the channel bottom of the river on Unionidae shells. Hempel (1899, p. 341) also found it in the Illinois River, from bottom towings. Richardson, between 1921 and 1928, reported the species from several localities along the Illinois River, namely: at Havana (1921, p. 440); in Peoria Lake below Chillicothe (1924, p. 380); at McKinley Bridge and Pekin, Illinois, in a strong current (1925, p. 417); and from LaSalle to Beardstown (1928, pp. 391, 407). Williams (1930, p. 280) reported *Urnatella* from Licking River in Kentucky. Rogick (1935, p. 258) found *Urnatella* in a number of Lake Erie, Ohio, localities. Several years ago specimens from Clinton River, Michigan, were sent to the senior author by Dr. C. J. D. Brown. *Urnatella* has been observed in Lake Dallas, Texas, by Dr. B. B. Harris and in the Mississippi River near Fairport, Iowa, by Dr. R. C. Osburn.

Paludicella articulata

Paludicella articulata is a dainty yellow to brownish form growing in fine traceries on all types of submerged materials (shells, rocks, etc.). It is closely adherent but when its branching is luxuriant and the substratum limited in area it forms a soft, loosely felted mat. Instead of forming statoblasts as do most freshwater bryozoa, *Paludicella* produces germinative bodies or "winter buds" called hibernacula (see Figs. 13, 15, 17, 18). These hibernacula are generally darker and much more opaque than the ordinary zooids. They are usually irregular in shape and split apart on germination but not so regularly as do statoblasts. The zooids are long, slender, spindle-shaped and linearly arranged. One or two zooids may sprout at an angle from the sides of each zooid (see Fig. 19). The zooids have a projecting, squared orifice. The tentacles number 16 to 18.

Paludicella articulata has a very wide distribution. In the present material it was found in abundance in the Michigan and Indiana samples (see Table II). It has previously been reported from a number of U. S. A. localities by Davenport, Richardson, Rogick and Ward. It has been reported by various writers from Belgium, Canada, China, England, Esthonia, Finland, France, Germany, Greenland, Hungary, India, Ireland, Italy, New Zealand, Norway, Russia, Scotland, Siberia and Switzerland.

Plumatella casmiana

There was some question as to whether this form should be called *Plumatella casmiana* or *Plumatella repens* var. *casmiana*. Dr. Toriumi, in his excellent 1942b

EXPLANATION OF PLATE II

FIG. 12. Sprig of a dead *Plumatella casmiana* zoarium showing somewhat angular, distinctly keeled zooids. Drawn to Scale C.

FIG. 13. Fragment of a pale-colored empty *Paludicella articulata* zooid from which the dark irregular hibernaculum had originated. Drawn to Scale B.

FIG. 14. Two *Urnatella gracilis* stalks attached to the same basal plate. Because this was preserved material some of the more distal segments are slightly collapsed and the calyces are missing. Drawn to Scale B.

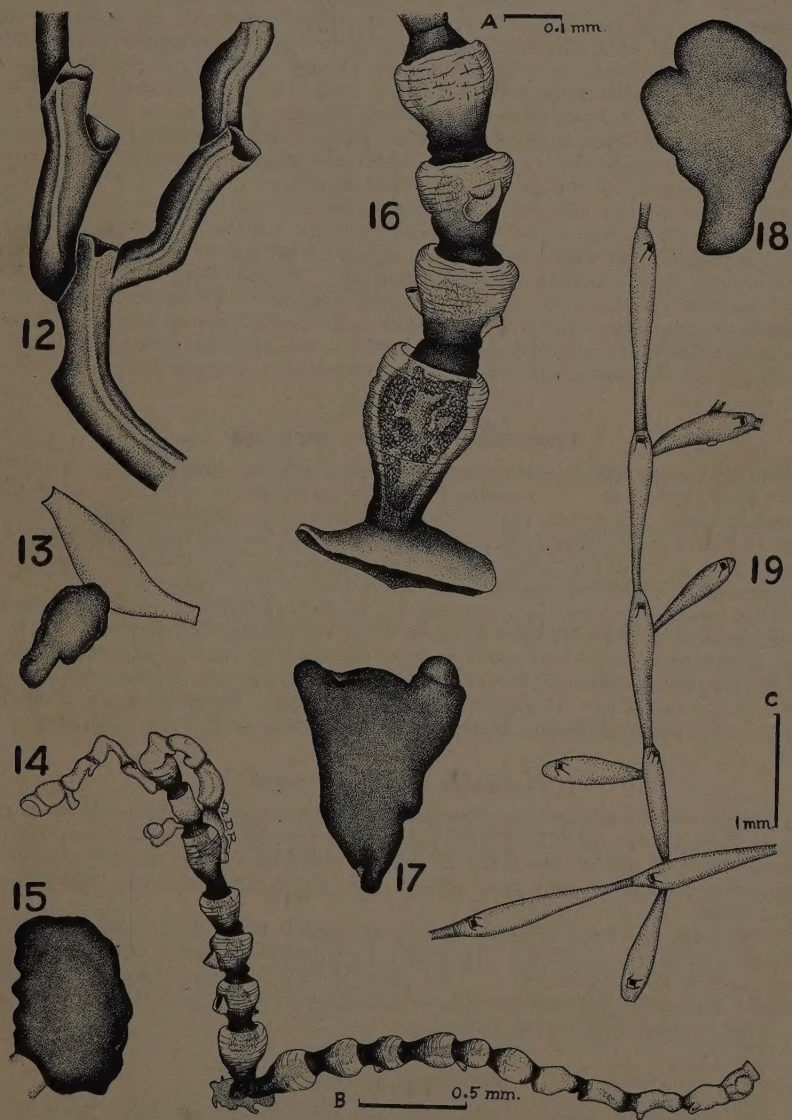
FIG. 15. A differently shaped hibernaculum of *Paludicella articulata*. Drawn to Scale A.

FIG. 16. A more detailed view of the basal plate and four lower segments of an *Urnatella gracilis* stalk. The brackets on the two middle segments represent broken off buds. Note the urn shape of the segments. Drawn to Scale A.

FIG. 17. Another differently shaped *Paludicella articulata* hibernaculum. Drawn to Scale A.

FIG. 18. Still another hibernaculum of *Paludicella*, drawn to Scale A.

FIG. 19. Portion of a *Paludicella articulata* colony showing the regular mode of branching (lateral and terminal). Drawn to Scale C.



paper (p. 209), prefers the latter classification because the forms of the colony and two types of statoblasts are so much like those of *Plumatella repens* var. *emarginata*. The present writers prefer the other classification (*P. casmiana*) because of the presence of the third type of statoblast (Figs. 10, 11). Should this peculiar, transparent, thin-walled type be found in other *Plumatella repens* varieties then *P. casmiana* unquestionably would be listed as a variety of *P. repens*.

Both Toriumi (1942b) and Rogick (1941, 1943) pictured the zoarium and two distinct types of floating statoblasts (floatoblasts). The present paper shows the third type of statoblast (sessoblast). By itself the *P. casmiana* sessoblast seems indistinguishable from that of *P. repens emarginata*. Measurements for two ordinary (capsuled, as in Figs. 8 and 9) floatoblasts are given in Table III. The zoarium or colony and the sessoblasts of *P. casmiana* and *P. repens emarginata* are very similar. The floatoblasts of *emarginata* when seen in edge view are flatter on the dorsal than on the ventral side and the dorsal side of the capsule is much more covered by the float than in *P. casmiana*. Compare Figs. 3, 4, 5 and 7, 8, 9.

Plumatella casmiana occurred in samples #558 and #613, from Michigan and Indiana, respectively. Kenk (1949, pp. 34, 57) reported this species from a pond in southern Michigan and Rogick (1941, 1943) from Lake Erie (Ohio and Canada). Foreign localities from which it has been reported are Formosa, Japan, U. S. S. R. and West Java.

Plumatella repens* var. *emarginata

The *P. repens emarginata* zoarium and sessoblasts are similar in appearance to those of *P. casmiana*. The zoarium is closely adherent, encrusting, tan to dark brown in color. The zooids are noticeably keeled. The floatoblasts are elliptical, slightly flatter on the dorsal side than on the ventral (see Fig. 5). The dorsal side float covers more of the capsule than does the ventral side float (see Figs. 3, 4). Measurements of several typical statoblasts are given in Table III.

This variety occurred in a number of Michigan, Indiana, Pennsylvania and Utah samples as listed in Tables I and II. It is widely distributed over the U. S. A. and elsewhere in the world and has been reported by many workers. Some of its interesting distribution records in foreign localities are: Africa; Asia (India, Java, Sumatra, Malay Peninsula); Europe (Belgium, Czechoslovakia, England, France, Germany, Hungary, Ireland, Italy and Russia).

Plumatella repens* var. *jugalis

The confused status of the geminate *jugalis* form was discussed in an earlier study (Rogick 1941, pp. 214-219). Very likely it is not a distinct variety but the growth form of one of the other *P. repens* varieties. Since the problem of its taxonomic status has not been solved the above unsatisfactory classification must be used.

This form has been reported only a few times since its discovery in Essex, England, by Allman in 1850. The present specimens were few in number and came from sample #558 (Michigan). The other North American (Ohio and Canada) collection sites for this form are in Lake Erie (Rogick 1935, pp. 253-254). There it occurred in considerable abundance.

Plumatella orbisperma

This species has been recorded only once in literature—in 1882, by Kellicott, from a pond on the border of Little Traverse Bay, Michigan. Unfortunately, it was incompletely described by Kellicott (1882, pp. 227-228). Only its nearly circular or orbicular statoblast was pictured. The statoblast measured about .325 mm. x .360 mm., with both sides nearly equally convex. The ectocyst was

described as colorless but not so thick as in *Hyalinella punctata*. The tentacle number was given as about 60. The description of the colony is inadequate so one can not really be sure to what genus this form belongs. Its floatoblasts very closely resemble in measurement and general appearance those of *Stephanella hina* which to date has been recorded only from Japan by Oka (1908) and Toriumi (1942a). However, *Stephanella hina* is described as having fewer tentacles (36-40), and has a sizeable ectocyst. The present writers have not found Kellicott's species but it would be an excellent idea for any collector who finds this form in the future to make a more detailed study of the species, particularly of the zoid anatomy and the zoarium growth habit.

SUMMARY

1. Five bryozoan species were found in nine collection samples. Of these nine samples five were from new Michigan localities, two were from Indiana, one from Pennsylvania and one from Utah.

2. A revision of identification and compilation of a list of previously reported Michigan Bryozoa is included. To date 11 species and varieties have been recorded from Michigan. The present study adds two more to the Michigan list: *Urnatella gracilis* and *Plumatella repens jugalis*.

3. *Paludicella articulata* was the most abundant bryozoan occurring in the Michigan and Indiana collections.

4. *Urnatella gracilis* was the next most abundant in the Michigan and Indiana collections.

5. *Plumatella repens emarginata* was the third most abundant form and occurred in the Michigan, Indiana, Pennsylvania and Utah samples.

6. *Plumatella casmiana* occurred in a Michigan and Indiana collection and was not especially abundant.

7. *Plumatella repens jugalis* occurred in very small quantity in one Michigan collection.

8. A *Plumatella casmiana* sessoblast is pictured for the first time but is indistinguishable from that of *P. repens emarginata*.

9. *Plumatella orbisperma* Kellicott 1882 is briefly discussed.

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